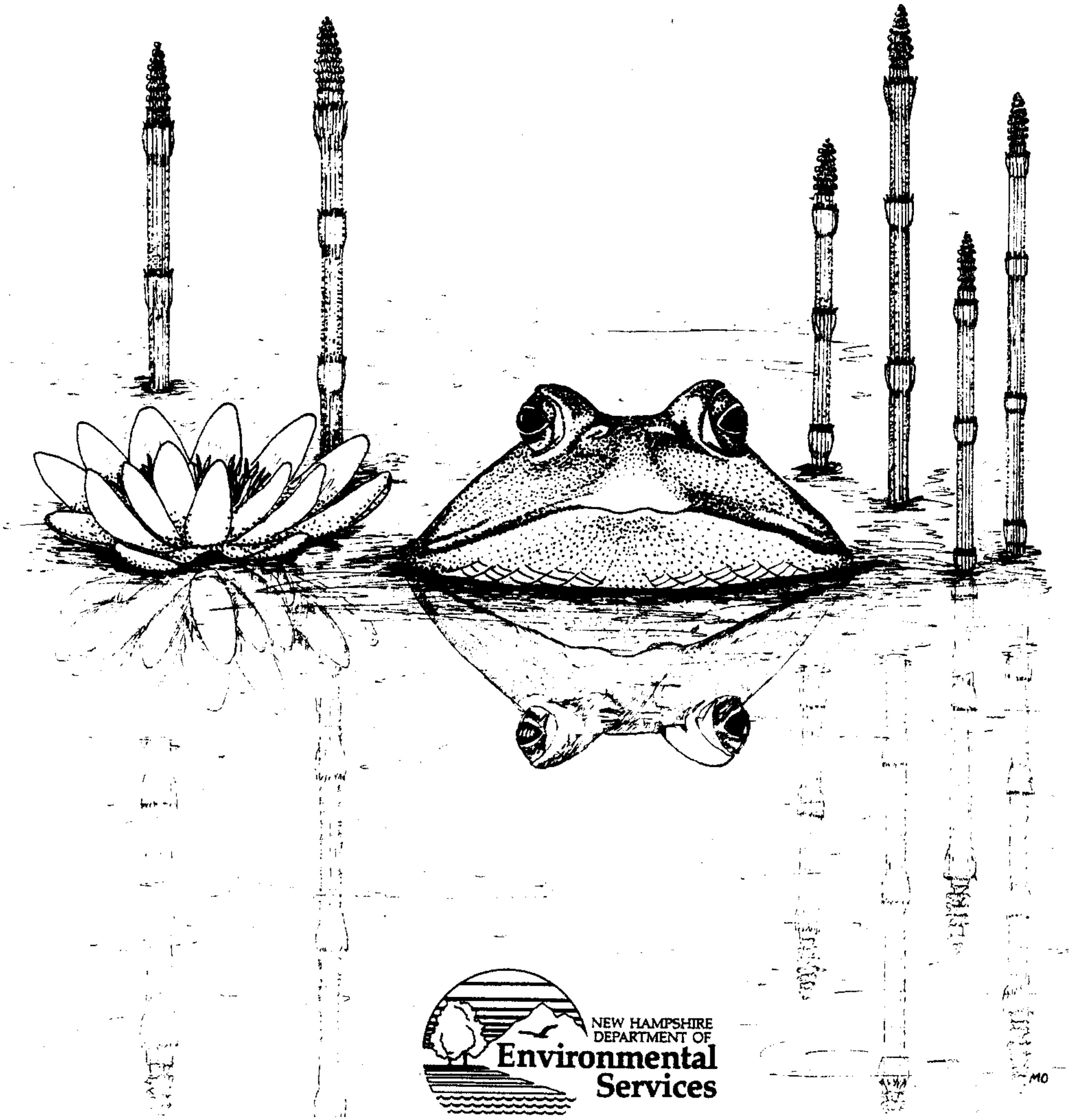
Staff Report
NHDES-WSPCD
92-15

Beaver Lake
Diagnostic/Feasibility Study



NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

State of New Hampshire
DEPARTMENT OF ENVIRONMENTAL SERVICES
6 Hazen Drive, P.O. Box 95, Concord, NH 03302-0095
603-271-3503 FAX 603-271-2867
TDD Access: Relay NH 1-800-735-2964

NHDES

January 15, 1993

Mr. Warren K. Howard, Program Manager
U.S. Environmental Protection Agency
Region I
John F. Kennedy Federal Building
Boston, Massachusetts 02203

Dear Mr. Howard:

Transmitted herewith is the Phase I Diagnostic/Feasibility Study for Beaver Lake, Derry, New Hampshire. This report was prepared, in part, under the Clean Water Act, through a Section 314 Environmental Protection Agency grant. This report culminates over 16 months of lake, groundwater and tributary monitoring, watershed evaluations and sediment characterization. Hydrologic and phosphorus budgets were constructed for each sub-watershed area of the lake.

Based on the biological and chemical assessment, and the modelling techniques employed, Beaver Lake falls into the Mesotrophic/Eutrophic classification scheme. Each of the major phosphorus sources to Beaver Lake were delineated.

The feasibility section provides an overview and recommendations for lake restoration and protection. This section focuses on decreasing non-point sources of phosphorus to Beaver Lake. Recommendations include utilizing Best Management Practices to decrease the phosphorus load to the lake from stormwater runoff and inflowing tributaries. The feasibility study also recommends sediment phosphorus inactivation as the most cost-effective technique to improve the lake quality. Lastly, the feasibility section provides a project implementation schedule that includes obtaining both Section 319 and 314 money to complete the Phase II Implementation Program.

Respectively submitted,

J Connor

Jody Connor
Clean Lakes Project Coordinator

Robert W. V

Robert W. Varney, Commissioner

RWV/JC/pdl

AIR RESOURCES DIV.
64 No. Main Street
Caller Box 2033
Concord, N.H. 03302-2033
Tel. 603-271-1370
Fax 603-271-1381

WASTE MANAGEMENT DIV.
6 Hazen Drive
Concord, N.H. 03301
Tel. 603-271-2900
Fax 603-271-2456

WATER RESOURCES DIV.
64 No. Main Street
P.O. Box 2008
Concord, N.H. 03302-2008
Tel. 603-271-3406
Fax 603-271-1381

WATER SUPPLY & POLLUTION CONTROL DIV.
P.O. Box 95
Concord, N.H. 03302-0095
Tel. 603-271-3503
Fax 603-271-2181

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

NHDES-WSPCD-92-15

Beaver Lake
Diagnostic / Feasibility Study

Final Report
December 1992

New Hampshire Department of Environmental Services
Water Supply and Pollution Control Division
Biology Bureau
6 Hazen Drive
Concord, New Hampshire O3301

Jody Connor
Marianne O'Loan
Authors

Robert W. Varney
Commissioner

John Dabuliewicz
Assistant Commissioner

Edward J. Schmidt, P.E., Ph.D.
Division Director

Robert H. Estabrook
Bureau Administrator

Printed on Recycled Paper

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

APPENDICES

ABSTRACT

The Beaver Lake Diagnostic/Feasibility Study presents over fifteen months of physical, chemical and biological data. This data was utilized to determine feasible and cost-effective means of preserving and restoring Beaver Lake.

The study accomplished all the objectives for which it was designed. The Study:

1. Identified the historical and existing water quality of Beaver Lake.
2. Identified the water quality of the Beaver Lake Tributaries.
3. Compared the trophic models that classified Beaver Lake.
4. Developed hydrologic and phosphorus budgets for Beaver Lake.
5. Documented significant sources of phosphorus to Beaver Lake.
6. Identified the importance of the lake's sediments to supply internal phosphorus loading to the lake.
7. Reviewed current lake restoration techniques and researched the feasibility of each method upon the lake.
8. Reviewed many watershed protection measures that will help to preserve the lake.
9. Made recommendations that will help improve lake quality and retard the eutrophication process.

The results and recommendations of the Beaver Lake Diagnostic/Feasibility Study provide a basis for lake preservation and possible implementation of lake restorative actions.

Although this project was successful in accomplishing its goals, only upon the implementation of the study's recommendations will it be a complete success.

ACKNOWLEDGEMENTS

The authors wish to acknowledge many individuals whose help and cooperation aided in the completion of this study and final report.

Special thanks to Robert H. Estabrook for his complete support of this special study and his editorial assistance of the report.

The Biology Bureau staff of this Department is acknowledged for its professional assistance in the field and laboratory. Particular thanks go to Kenneth Warren, Douglas Dubis, Walter Henderson, Patricia McCarthy, Natalie Landry, Kendall Perkins, Steve Landry and Matthew Bowser who spent many hours under adverse weather conditions, recording stream flows, sampling the lake and measuring groundwater seepage. Also, thanks to our summer interns Tom Morrison, Jessica Young and Greg Benoit for assisting in field work and conducting many of the laboratory analyses needed for this study.

Special thanks to Douglas Dubis for coordinating the computer data bases.

The efforts of Garry Haworth for coordinating the chemical analyses program was greatly appreciated.

Members of the Citizens Advisory Committee (C.A.C.) are thanked for their participation in the study, and for their concern and dedication in the protection of Beaver Lake. Special thanks go to Jim Hennessy for hosting our first meeting, and to Jeffrey Lange for all his help and for allowing us access to Jenny-Dickey Brook.

Additional thanks go to the lake front property owners who allowed us to install seepage meters in front of their homes, and the conservation committee members who have supported this study.

We are grateful to Region 1 of the United States Environmental Protection Agency for their financial assistance, and particularly Warren Howard for his support and guidance during all phases of this project.

Lastly, a most appreciative thanks goes to Paulette LaRamee for her many hours of typing this document, as well as her insight and persistent efforts to arrive at an organized and impressive report.

Beaver Lake Citizens Advisory Committee

Norma Bursaw
Derry, NH

Daniel Carradini
Derry, NH

Bruce Clark
Derry, NH

Jody N. Connor
Concord, NH

Fran Cormier
Derry, NH

Michael and John Doherty
Derry, NH

Albert Doolittle
Derry, NH

Jack Dowd
Derry, NH

Charles Gibbons
Derry, NH

Joe Gould
Derry, NH

Jim Hennessy
Derry, NH

Jeffrey Lange
Derry, NH

Marianne O'Loan
Concord, NH

Donna Ouelette
Derry, NH

Dick Phelan
Derry, NH

Patricia and Sarah Steele
Derry, NH

Pat and Robert Tompkins
Derry, NH

Robert Tompkins, Jr
Derry, NH

Constance Ward
Derry, NH

Martha Warren
Derry, NH

Tom Wiley
Derry, NH

GLOSSARY OF TERMS

ACID PRECIPITATION: Precipitation having a lower than normal pH (higher acidity) resulting from the oxidation of sulfur and nitrogen oxides, present in the atmosphere, into sulfuric and nitric acid.

A.N.C.: Acid Neutralization Capacity, also known as alkalinity. Refers to the quantity and kinds of compounds present which shift the pH to the alkaline or basic side of neutrality.

ANOXIC: Lack of oxygen (also, anaerobic)

BATHYMETRIC CHART: A map depicting the depth contours of a lake bottom.

BENTHIC: Referring to bottom zones or bottom-dwelling forms.

BIOMASS: The weight of all living material in a given area at a given time.

EPILIMNION: The upper, well circulated, warm layer of a thermally stratified lake.

EUTROPHIC: Nutrient rich waters, generally characterized by high levels of biological production.

FLUSHING RATE: The number of times a volume of water equal to the lake volume passes through the lake in a given year.

HYDROLOGIC BUDGET: A compilation of the total water inputs and outputs to and from a lake.

HYPOLIMNION: The deep, cold, relatively undisturbed bottom waters of a thermally stratified lake.

LIMITING NUTRIENT: An essential substance for plant growth which is present in the environment in the least amount relative to the needs of the plant.

LOADING: The amount of a substance that is added to a lake during a specified time period.

MESOTROPHIC: Waters containing an intermediate level of nutrients and biological production.

METALIMNION: The middle layer of water in a thermally stratified lake, between the epilimnion and hypolimnion, where the decrease in temperature with depth is at its greatest.

NUTRIENTS: Inorganic substances required by plants to manufacture food by photosynthesis. Phosphorus is the nutrient that usually limits the amount of plant growth in New Hampshire lakes.

OLIGOTROPHIC: Nutrient poor waters, generally characterized by low biological production.

PHOSPHORUS MODEL: A mathematical equation that predicts the in-lake phosphorus concentration, based on the phosphorus inputs and various morphologic and hydrologic characteristics. It is used to predict the effect of changes in phosphorus inputs on the lake's water quality.

PHOTIC ZONE: The depth of lake water that receives sufficient sunlight to permit photosynthesis.

PHYTOPLANKTON: Microscopic plant life that float within or on top of lake water.

PLANIMETER: An instrument used to measure the area of any plane surface by tracing the boundary of the area.

PRIMARY PRODUCTIVITY: The rate of producing organic matter from inorganic substances by photosynthesis.

PRODUCTION: The weight of new organic matter formed over a period of time plus any losses during that time.

RUNOFF: Precipitation that enters surface waters from overland flow and from groundwater.

THERMAL STRATIFICATION: Horizontal layers of water, arranged from top to bottom in order of increasing density due to differences in temperature.

THERMOCLINE: The point of maximum temperature decrease with depth in a thermally stratified lake. Diagramatically, it is where the temperature profile curve switches from concave upward to concave downward.

TROPHIC STATE: The nutritive state of a lake or, more specifically, the level of the plant nutrient phosphorus. It is often described, however, in terms of the biological production in the lake.

WATERSHED: The total area draining into a lake, including the area of the lake itself. Also called drainage basin.

WET POND: Also known as retention pond. Basin designed to collect stormwater runoff and remove sediment, B.O.D., organic nutrients and trace metals. May be planted with aquatic macrophytes to remove soluable nutrients.

EXECUTIVE SUMMARY

A. Introduction

The Beaver Lake study began in October of 1989 as a result of a Section 314, Clean Lakes Program grant.

The Beaver Lake watershed spans two municipalities in the southeastern portion of the State of New Hampshire. Approximately 76.4% of the watershed lies in the Town of Derry and 23.6% lies in the Town of Chester.

The goal of the diagnostic study was to determine the phosphorus inputs to Beaver Lake and to identify the problem areas of significant phosphorus loading.

The goal of the feasibility section was to evaluate the methods that can be utilized to preserve and if necessary, to restore Beaver Lake, and to recommend the most feasible, cost-effective methods for implementation.

B. Study Approach

Prior to recommendations being made for protective and restorative measures a fuller understanding of such processes as lake flushing rates, groundwater influences, watershed utilization, sediment characteristics and nutrient sources had to be achieved. To this end, biologists began a 15 month study to document the physical, chemical and biological processes of Beaver Lake. Refer to the glossary to aid in understanding of technical terms.

1. Physical, Chemical, and Biological Monitoring

Measurements of water chemistry, plankton populations, chlorophyll-a, and transparency were recorded. An inventory of macrophytic growth was documented, and a detailed map and evaluation of the pond's littoral areas were completed. Sediment cores were extracted and analyzed for specific metals and phosphorus. Land use, topographical ground cover, and soils maps for the entire watershed were prepared.

2. Hydrologic Budget

The hydrologic budget for the gaging period (February 1990 through January 1991) quantified all significant sources of flow into Beaver Lake by gaging tributaries and outlets, estimating direct surface runoff, measuring precipitation and evaporation, and estimating groundwater seepage rates.

3. Nutrient Budget

Phosphorus loading, the primary factor limiting plankton growth, was determined through water quality sampling and analysis of many of the sources quantified in the hydrologic budget. Groundwater, atmospheric dryfall and direct runoff inputs were estimated. Phosphorus loading to the lake from near-shore septic systems was planned but not implemented because of the concurrent sewer project which occurred during the time of our study. The quantities of water column and sediment phosphorus concentrations were calculated, and a nutrient budget was prepared for the study year.

4. Lake Modelling

The determination of the trophic state of a lake involves a comparison of the actual total phosphorus loading to the lake with the maximum loadings that the lake can tolerate before excessive algal and macrophyte growth occurs and transparency diminishes. A trophic state model is a mathematical relationship which, by incorporating such factors as phosphorus loading and hydraulic retention time, allows a lake to be classified as oligotrophic, mesotrophic, or eutrophic. Four different classification methods were utilized and their results are compared for this study.

C. <u>Study Results</u>

1. Chemical and Biological Properties

Beaver Lake is a typical dimictic lake insomuch as it stratifies into three layers during the summer months and has two mixing periods, the vernal and autumnal overturns, each year. During the summer months, the deepest water layer (all the water below the depth of 6 meters) exhibits anoxic or very low dissolved oxygen content conditions.

The lowest tributary pH was at the Beaver Lake Ave Culvert station while the highest was at the Rte 102 inlet. B.L.A.C. had the lowest consistent pH values. Acid neutralizing capacity (ANC) data was limited. B.L.A.C. and Manter Brooks had lower ANC values than observed at other stations.

Epilimnetic pH ranged from 6.56 to 7.58 during the monitoring period. Metalimnetic pH values were 0.1 to 0.5 units lower than epilimnetic values. Most observations of ANC in Beaver Lake ranged from 12 to 24 mg/L as $CaCO_3$. Mean tributary specific conductance ranged from 66.3 umhos/cm (B.L.A.C. Tributary) to 520.0 umhos/cm (Cat-O-Swamp). In-lake specific conductance ranged for the most part between 151 and 168 umhos/cm. Hypolimnetic conductivity was slightly higher during the study.

Median monthly chloride concentrations ranged from 7 mg/L (B.L.A.C.) to 122.0 mg/L (Cat-O-Swamp). In-lake chloride concentration ranged between 22 and 27 mg/L.

Mean tributary sulfates ranged from 8.4 mg/L to 18.0 mg/L. The majority of the values fell within 9 to 12 mg/L. In-lake sulfates ranged between 4.0 and 4.8 mg/L.

Median apparent color of the tributaries for the study period ranged from 7 to 94 cpu. Color values observed at the B.L.A.C. tributary were significantly lower than other tributary stations. Development Brook's color values were higher than those colors observed at other stations. Monthly in-lake apparent color in the three stratified layers ranged from 16 to 110 cpu.

Observations of tributary turbidity did not follow expected patterns. The majority of the tributaries had seasonal highs in the fall. Turbidity fluctuated in the other tributaries and may have been due to construction of the sewer line.

Total phosphorus mean concentrations for the study period ranged from 13.1 ug/L to 57.9 ug/L. The greatest phosphorus concentrations were observed at Clark Brook and B.L.A.C. stations, while the lowest concentrations were observed at the lake's outlet at Development Brook. Monthly in-lake concentrations of total phosphorus ranged from 6 ug/L to 90 ug/L. The highest in lake concentrations were measured in the thermocline.

Nitrate nitrogen mean values ranged from .06 to 1.15 mg/L in the tributaries and from .39 to .77 in the lake samples. Mean total in-lake Kjeldahl nitrogen (TKN) ranged from 0.29 to 0.47 mg/L. Mean tributary TKN ranged from .10 mg/L to 2.00 mg/L. The Rte. 102 tributary had significantly higher mean TKN values due to a single high sampling result.

In-lake phytoplankton density ranged from 900 to 1500 cells/mL and the population was typically dominated by Chroomonas or Cryptomonas.

The rotifers Kellicottia and Keratella and Nauplius larvae were the most common observed species of zooplankton. Microcrustacea were dominant only during January.

Chlorophyll-a concentrations ranged from 2.47 to 7.09 mg/m^3 with the mean chlorophyll-a concentration of 6.10 mg/m^3.

2. Hydrologic Budget

A Hydrologic budget was prepared for the Beaver Lake watershed and is discussed in Chapter VII.

Manter Brook was the greatest single source of water to Beaver Lake and contributed 69 percent of the total inflowing water. Groundwater seepage, direct runoff and precipitation combined to account for seven percent of the hydrologic budget. The other major contributors were Jenny-Dickey Brook and Cat-O-Brook (10 percent each). The remaining tributaries contributed four percent collectively.

3. Nutrient Budget

One of the most important goals of this study was to quantify the various avenues of phosphorus inputs to Beaver Lake. Chapter VIII includes an annual phosphorus budget for the 1990 gaging year.

The greatest single contributor of phosphorus to Beaver Lake was Manter Brook which contributed 44 percent of the external phosphorus load. Difficult to monitor sources, such as septic leachate, groundwater seepage, direct runoff and atmospheric deposition were calculated to contribute 35 percent collectively. Those tributaries that supplied less significant phosphorus sources were Jenny-Dickey Brook (10 percent), Cat-O-Brook (6 percent) and Cat-O-Swamp (2 percent).

Monitoring showed that Manter Brook had the greatest storm event-induced export of phosphorus to Beaver Lake.

4. Lake Modelling

A summary of the four classification schemes utilized in this study revealed that the New Hampshire Lake Classification System classified Beaver Lake as eutrophic. The Dillon/Rigler Model and Vollenweider phosphorus loading model classified Beaver Lake as mesotrophic and mesotrophic/eutrophic respectively. The Carlson Trophic Status Index defines a trophic class for several parameters. Secchi disk transparency measurements in Beaver Lake and phosphorus concentration fell into the mesotrophic range while chlorophyll-a measurements were in the mesotrophic/eutrophic range.

On a permissible loading basis, the Dillon/Rigler Model demonstrated that it would take an increased load of 255 KgP/yr to decrease the lake quality enough to reflect characteristics of borderline mesotrophic/eutrophic conditions.

5. Feasibility

This section provides an overview of the most recent available restoration and preservation techniques. Each restoration technique was divided into methodology, cost/benefits and applicability to effectively produce positive water quality results to Beaver Lake.

The most feasible means of lake protection, watershed management and restoration of Beaver Lake should include the following measures:

1. Shoreland Protection Ordinance
2. Community Education
3. Volunteer Monitoring
4. Education and BMP Practices for Hobby Farms
5. Best Management Practices for Silviculture
6. Restricted and Permitted Land Use
7. Stormwater Runoff Management
8. Wet Pond Construction
9. Sediment Phosphorus Inactivation
10. Lake Monitoring/Phase II Implementation Evaluation

CHAPTER I

I. INTRODUCTION

Lakes are important resources in New Hampshire. They provide enjoyment in fishing, swimming, and boating, and they enhance the beauty of the natural environment. Their value for tourism amounts to many millions of dollars each year. The recreation and tourism industry in New Hampshire plays a vital role in many communities and in the state economy. However the increased intensity of use of these water bodies has resulted in the aesthetic degradation of many lakes throughout the state. The same people that were attracted to these lakes and ponds because they were clean, clear and tranquil are now complaining of diminished quality as well as overdevelopment.

To accomodate this growth in lake use, lake and watershed management has become increasingly important in the last twenty years. Limnologists are now trying to educate the public on the importance of lake preservation before the resource is destroyed and it becomes necessary to spend thousands of dollars on lake restoration.

The Beaver Lake Study began in October of 1989 and was partially funded by a Section 314, Clean Lakes Program grant. The project afforded limnologists the opportunity to study and to better understand Beaver Lake and its watershed.

Although the Beaver Lake watershed spans two municipalities, most of the watershed area is in the Town of Derry. The watershed area encompasses approximately 6900 acres and is the drainage basin of several smaller ponds and an extensive system of tributaries.

A priority list developed by the Department of Environmental Services ranked Beaver Lake third in the state for restoration and preservation, placing it in the very high priority category. The lake is located within 15 miles of both Manchester and Nashua, the state's two largest cities. Within the past twenty years the Town of Derry's population has swelled in response to the migration north of the Boston bedroom community. A subsequent effect of this population increase is the increasing stresses on the natural resources of the area.

The goal of this study was to determine the sources of these stresses. To achieve this end, hydrologic and nutrient budgets for the lake were determined and problem areas in the watershed were delineated.

The goal of the feasibility section was to describe some of the methods available to both improve the lake and protect it from further degradation. The implementation of these recommendations will be dependent upon the initiative of state and local government, the citizens of Derry and the shoreland and critical watershed property owners of Beaver Lake. Cooperation will be a key element in establishing the implementation goals. One of the greatest challenges, that of working together to meet our water quality goals, still lies ahead.

II HISTORICAL DATA

A. Historical Events In Derry NH

The first European settlers to the Town of Derry arrived in 1718. They were primarily of Scotch-Irish descent and emigrated to the new world from Ireland in search of religious freedom. The band was led by Presbyterian Reverend McGregor, who is known to have preached his first sermon on the shores of Beaver Lake.

The sixteen families that founded what is presently Derry settled on land north of Haverhill, Massachusetts, and named their settlement Nutfield for the abundance of nut-bearing trees found there. The settlers quickly built homes along the shores of a stream which they called West Running Brook, and what is the tributary from the outlet of Beaver Lake. They also constructed several garrisons for protection in the event of an indian attack, which they thankfully never needed. The settlers constructed a sawmill and a gristmill along the outlet tributary, and cleared a common field where the first white potatoes in the country were cultivated. The settlers also cultivated flax and wove the first linen in North America. The quality of the linen was fine and both Presidents Washington and Jefferson are known to have worn shirts bearing its seal.

In 1720 the first road was laid out, running between the upper and lower villages of the settlement. Two years later, Nutfield was incorporated into the Town of Londonderry, which was named after the town in Ireland from which most of the settlers had originated.

Londonderry sent a large number of men to serve in the Revolutionary War. The most notable figures from Derry included Matthew Thornton, signer of the Declaration of Independence, and General John Stark, the hero of the Battle of Bennington.

A prime factor in determining the growth of a town is its transportation routes. In 1804 the town legislature approved plans to build the Londonderry Turnpike, a span of road which stretched from Concord, New Hampshire to the Massachusetts' state line at Andover, now known as Bypass 28. This new road paved the way for the resulting growth of Londonderry by allowing greater accessibility and mobility for both goods and people.

As the population grew in size the town borders expanded. By 1827, Londonderry had enlarged to the point of division. Two hundred and ninety five people petitioned the legislature to divide the town. The western portion retained the name Londonderry and the eastern portion was set off into a separate township called Derry.

The Township of Derry was divided into two major areas, the upper village and the lower village. The business center of town was located initially in the upper village. Here was located the town hall, the church, the bank and several stores. Soon, the village was expanding and adding businesses. Due to the abundance of rivers and brooks in the area many mills were established, including a gristmill, a fulling mill, a sawmill, two carding mills and shingle mill.

The construction of the Manchester and Lawrence Railroad in 1849 shifted the town's business center to West Derry, where the railroad depot lay. This additional transportation route supplied easy access to major nearby cities including Lowell, Haverhill and Boston, Massachusetts, Nashua and Manchester, New Hampshire and Portland, Maine. This new route allowed expansion of H.P. Hoods milk delivery business, and caused the company to prosper for many years after. The Hood's prosperity directly affected the town's growth as the members of the family were well known benefactors and supplied the town with gifts of land, buildings and a school. They also established needed social programs.

Though transportation routes were well established by the 1850's, it was not until after the Civil War that the Industrial Revolution hit Derry. By the end of the century Derry's economy had veered primarily from that of farming to that of shoe manufacture. The most notable manufacturer in Derry was the W.S. & R.W. Pillsbury Co. which owned 18 buildings in West Derry and could produce up to 4,500 pairs of shoes daily.

Another prosperous business at this time was the Benjamin Chase Co. which produced reed ribs used in the manufacture of cloth. The company grew and prospered and continues to produce wooden products to this day, including tongue depressors and horticultural stakes.

New inventions soon hit Derry and expanded its contact with the outside world. The telephone arrived in Derry in the early 1880's, connecting it to Manchester and all lines radiating from there. Electricity soon made its debut and by the early 1890's the town was equiped with electric lights from the Derry Electric Light Co. This aided the growth of transportation also, and by the early 1900's the horse and buggy had been replaced by steam and electric locomotives and automobiles. It was very soon after this that the gasoline powered automobile was built and began to assert its dominance over other means of transportation.

The early 1900's saw much growth in the town, in the form of not only new businesses and buildings and churches but many social and philanthropic organizations. The shoe factories were doing well and expanding, as were many other merchants. However, the depression eventually struck the town, as it did the rest of the nation. It is interesting to note that although many businesses failed, Derry continued to produce shoes throughout those lean years.

At the time of the arrival of the Second World War Derry was again prospering, and continued to do so during the war years. The post-war baby boom brought the problems of overcrowding in the schools, and several new ones were opened or expanded, including the new Hood Jr. High School which was donated by Mrs. Gilbert Hood.

At this time passenger trains ceased to service the town, and since 1953 only freight trains have traveled the route to Derry.

The 1960's were ushered in with the tragic Chelmsford Shoe Factory fire. Within an hour of its outbreak the fire had decimated four large tenement buildings, a dozen homes, a store and the shoe factory itself. It brought firefighters from towns within a hundred mile radius. This fire marked the end of shoemaking as Derry's principal industry.

On May 5, 1961 Derry became known as "Spacetown, USA" as one of its own, Alan B. Shepherd, Jr., became the first man from this continent to enter outer space. Later, he went on to participate in the Apollo 14 mission. The town designated a section of the new highway (Rte. 93) to be named after him, the "Alan B. Shepherd Memorial Highway". This new high speed highway changed the future of Derry considerably, as if allowed better access to the nearby big cities. People from Boston and its surrounding towns became attracted to Derry for its rural charm and low taxes, and Derry once more began to develop and change with the new population pressure. New industries were located in town along with several large apartment house complexes and shopping centers. It continues to grow to this day as the Boston bedroom community expands into Southern New Hampshire.

B. Uses & Access Points

Beaver Lake is easily accessible for the public. It lies in the eastern quarter of Derry, which can be reached from the North or South by Interstate 93, and from the Northeast or Southwest by Rte. 102. The lake boasts several beaches, at least one of which is public. There is a well maintained public boat launch which provides parking for up to 15 cars and trailers.

Many different types of recreational activities have occurred at Beaver Lake since its shores were settled. Historical records show that it was a popular recreation area in the early 1900's. Swimming, boating and fishing were commonly enjoyed activities, and remain so today. The lake was also enjoyed in the winter, especially during the Derry winter carnival when skating, ice fishing and horse racing occurred on its surface.

Another prime attraction at that time was the Beaver Lake Pavillion which was situated in the area that now includes Comeau's Beach . The pavillion was built in 1896 by the Chester & Derry Railroad as an attempt to draw business to their new trolley line. The pavillion drew not only townspeople but vacationers from all areas. A prime attraction at the pavillion was weekend dancing and it was the host of many other gatherings.

Beaver Lake is still a popular recreation area. In the warmer months boating, swimming and water skiing are enjoyed. The Derry Recreation Committee has sponsored many programs at the town beach. These have included a handicapped adaptive program, canoe and kayak lessons and water exercise classes. Snowmobiling, cross country skiing and skating are activities enjoyed in the winter.

Fishing is a popular sport year round at Beaver Lake with trout, bass and horned pout being common catches. The Fish and Game Department has stocked the pond yearly since 1972 (and for a span of time in the late 40's and early 50's) with yearling brook and rainbow trout.

In addition to recreational uses the waters have supported many practical ones as well. Much of Derry's early industry utilized the plentiful energy source of its waterways. Many different types of mills were powered by the outlet such as furling, corn, carding, shingle, cider and sawmills. In addition to this the lake has served as both water and ice sources.

C. Historical Water Quality Data

Historical water quality data from Beaver Lake was first collected in 1938 by the Fish and Game Department, and then again in 1953. This data is presented in Table II-1. The next subsequent sampling began in 1984 when the Derry Conservation Commission, along with the Beaver Lake Association, joined the UNH Lay Lakes Monitoring Program and monitored the lake for 4 years. Many parameters were studied by both Fish and Game and the UNH group that we also investigated in our Diagnostic/Feasibility study. These included temperature, dissolved oxygen, conductivity, A.N.C. and pH. However, it must be kept in mind that the procedures used by the other groups for analysis of these parameters differ from those that were used in our study of the lake, and the differences in values cannot therefore be entirely contributed to lake quality changes. However, gross trends can be inferred from the data and are discussed below.

The Fish and Game data was first collected on June 30, 1938. Biologists working on the survey were interested in studying those parameters which would most likely affect the fish populations of the lake. They analyzed the lake at several depths for temperature, oxygen, A.N.C. and pH. The most notable difference from the quality of the lake today can be observed in the dissolved oxygen content of the lower waters, which showed an abundance at that time. The pond was designted as salmonoid water (capable of sustaining cold water fisheries) and stocking began of both warm water and cold water fish species. The management continued until the early 50's when the next survey was completed.

Fish and Game biologists again sampled the pond on July 24, 1953. This data is also shown in Table II-1. Here we can observe the beginning of the dissolved oxygen deficit trend in the lower waters of the lake. This may be due in part to increased usage of the waters. During the span of time between the two sampling dates from the 1930's to the 1950's the population of the Town of Derry increased by 13.6%. Historical population figures are given in Appendix II-1.

Other notable comments from the 1953 survey include the analysis of the shoreline. At that time the shoreline breakdown was estimated at 90% wooded and 10% meadow. The bottom cover was estimated in 1953 to be composed of 25% gravel, 25% rock and 50% sand. In a current survey of the lake you would be hard pressed to find any sand on the shoreline that was not trucked in from an outside source.

Table II-1

Fish and Game Data for Beaver Lake

Date	Depth (ft)	Temp (°F)	O_2 (ppm)	ANC (MO/ppm)	pH (units)
6/30/38	0	65.0	7.8	15.0	7.0
	10	63.5	7.9	---	7.0
	20	61.0	6.3	12.5	6.4
	22	59.0	5.4		6.4
	30	55.0	4.4	12.0	6.4
	37	51.0	4.1	8.0	6.4
Date	Surf	76	7.5	9	7.2
7/24/53	10	76	7.6	12	7.2
	15	72	---	---	---
	18	58	---	---	---
	20	58	7.6	11	7.2
	30	55	5.8	10	7.2
	35	55	1.0	11	7.2
	40	51	1.0	9	6.1

The next documented data on Beaver Lake was collected by the Biology Bureau in 1976 and 1977. At this time the lake was classified as eutrophic and showed a well-developed hypolimnetic oxygen deficit. Vascular plants around the shoreline were rated as very abundant. The pH and A.N.C. values remained in the range of the prior Fish and Game surveys.

The cultural factors noted on the survey make reference to a 1963 study indicating that 55% of the shoreline was developed, but at the time of the 1977 survey this number had risen to 99%.

The next survey was conducted by the Biology Bureau in 1984 at the request of the town, and was repeated in 1985. Classification of the pond remained eutrophic. Overall weed growth declined while algal growth increased and the algal population shifted to being dominated by less desirable species. The lake still showed marked dissolved oxygen deficits in the lower waters, and declining water clarity, pH and A.N.C. trends were noted. Tables II-2 through II-4 depict the historical surveys.

The 1984 season marked the beginning of participation in the U.N.H. Lay Lakes Monitoring Program by concerned citizens. This sampling continued for 4 years and the results were published by the group (available on request at U.N.H.). Their sampling included both the lake stations and several major tributaries.

The lake data collected was within the same general boundaries of that collected by the Biology Bureau. In their report, the Freshwater Biology Group noted that the Secchi disk transparency readings were declining and that the conductivity, especially in the lower layers of the water was much greater than previous years.

The stream data was also within the same general range of the Biology Bureau data. It should be noted that our total phosphorus figures are higher than UNH's. The LLMP data is summarized in Tables II-5 and II-6.

TROPHIC CLASSIFICATION OF N.H. LAKES AND PONDS

NAME Beaver Lake TOWN Derry CO Rockingham RIVER BASIN Merrimack

I. POTENTIAL FOR NUTRIENT ENRICHMENT

A. NATURAL PHYSICAL FACTORS

1. Area (ha) 54.07
2. Max. depth (m) 13.7
3. Mean depth (m) 4.8
4. Elevation (ft) 290
5. Shore length (m) 5800
6. Volume (m^3) 2,614,000
7. Volume/shore length 450
8. % Stratification 22
9. Watershed area (ha) 2792.0
10. Watershed area / Volume 10
11. Bottom slope 1.7
12. Shore config. 2.23
13. Flushing rate 5.1
14. Water renewal time 0.2
15. Drainage density -
16. % Watershed ponded 0.6
17. Phos. retent. coeff. R 0.45

B. CULTURAL FACTORS

1. % Shore developed 55% (1963)
2. Number nearshore homes
3. # nearshore homes/mile shore
4. Volume lake/# nearshore homes
5. Estimate of non-point Tot-P loading:
   a. Land Use
   b. Precipitation
   c. Subsurface disposal
   d. Other

II. INDICATORS OF TROPHIC CONDITION (mg/l unless indicated otherwise)

A. Winter Data:

Date February 11, 1976 Weather Partly cloudy and windy

Depth(m)	1.0	
Alkalinity	16.0	
PO_4-P	0.005	
Total-P	0.017	
NO_2+NO_3-N	0.42	
Kjeld-N	0.35	
Total-N	0.77	
Tot-N/Tot-P	45.3	
NO_2+NO_3-N/PO_4-P	84	

Bottom: Depth 10.0m D.O. 8.1 % Sat. 59

% Organic matter sediment 22.0

Dom. Phytopl. 1. Asterionella - 90%
2.

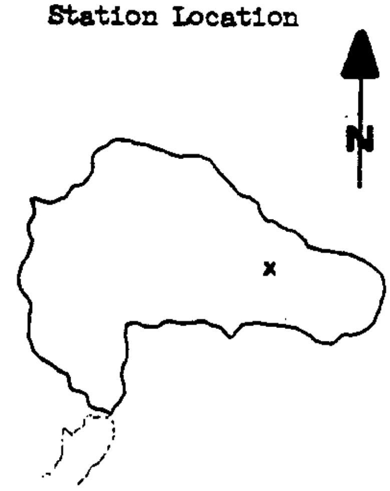
Dom. Zoopl. 1. Nauplius larva - 60%
2. Diaptomus - 10%

B. Summer Data:

Date August 16, 1977 Weather Hazy to clearing, light breeze 70°

	Mid-ep	Mid-therm	Mid-hyp
Depth (m)	1.5	5.0	10.0
pH (units)	6.6	6.9	6.4
Alkalinity	12.5	12.5	16.5
PO_4-P	< .001	0.009	0.008
Total-P	0.018	0.016	0.036
NO_2+NO_3-N	0.10	0.11	0.10
Kjeld-N	0.27	0.29	0.40
Total Residue	59	-	-
Color (units)	30	30	70
Turb. (NTU)	0.8	1.0	8.4
Spec. Conduct. (μMhos/cm)	76.7	76.0	79.0
Tot. Org. Carbon	3.0	-	-
Chloride	9.1	9.1	8.7
Mg	0.99	-	-
Ca	6.8	-	-
Na	5.2	-	-
K	1.4	-	-
[Mg+Ca] / [Na+K]	1.18	-	-
Tot-N/Tot-P	20	25	14
NO_2+NO_3-N/PO_4-P	-	12	12

Station Location



Bottom: Depth 13.0 m D.O. 0.0 % Sat. 0

Epilimnetic alkalinity decrease 3.5

PO_4-P ratio: epi/hyp .12

Total-P ratio: epi/hyp 0.50

Secchi disk transparency (M) 4.8

% organic Matter sediment -

Vascular Plants Very Abundant

Dom. Vasc. Plants: 1. Potamogeton robbinsii
2. Vallisneris
3.

Ash-Free Dry Weight

Chlorophyll a 3.28 (mg/m^3)

Tot. Zoopl. Cnts. 577 (cells/liter)

Dom. Phytopl. 1. Ceratium - 85%
2.

Dom. Zoopl. 1. Nauplius larva - 15%
2. Difflugia - 15%
3. Keratella - 15%

TROPHIC CLASSIFICATION 1977 :

	D.O.	S.D.	Vasc. Plants	Chl a	Total	Class.
Classification Points:	6	1	4	0	11	Eutro.

COMMENTS:

NEW HAMPSHIRE WATER SUPPLY AND POLLUTION CONTROL COMMISSION

LAKE TROPHIC DATA

MORPHOMETRIC:

LAKE	Beaver Lake	LAKE AREA (HA)	54.07
TOWN	Derry	MAXIMUM DEPTH (M)	13.7
COUNTY	Rockingham	MEAN DEPTH (M)	4.8
RIVER BASIN	Merrimack	VOLUME (M^3)	2,614,000
LATITUDE	42° 54' N	MUD SURFACE AREA (HA)	126.40
LONGITUDE	71° 18' W	RELATIVE DEPTH	1.7
ELEVATION (FT)	290	SHORE CONFIGURATION	2.23
SHORE LENGTH (M)	5800	AREAL WATER LOAD (M/YR)	10.60
WATERSHED AREA (HA)	2792	FLUSHING RATE (YR^{-1})	5.1
% WATERSHED PONDED	.01	PHOSPHORUS RETENTION COEFF.	.45

BIOLOGICAL: DATE	14 Feb 1985	5 SEP 1984
DOM. PHYTOPLANKTON (% total) 1	Asterionella (100%)	Oscillatoria (55%)
2		Dinobryon (20%)
NUMBER OF ALGAL GENERA	4	11
SPECIES DIVERSITY	<.1	2.22
CHLOROPHYLL a (ug/L)		7.02
DOM. ZOOPLANKTON (% total) 1	Nauplius larvae (55%)	Nauplius larva (20%)
2	Keratella (25%)	Keratella (20%)
ROTIFERS/LITER	34	46
MICROCRUSTACEA/LITER	84	37
TOTAL ZOOPLANK. CNTS (cells/L)	124	101
VASCULAR PLANT ABUNDANCE		Abundant
DOMINANT VASCULAR PLANTS 1		Potamogeton Robbinsii
2		Potamogeton amplifolius
3		
SECCHI DISK TRANSPARENCY (M)		3.4
BOTTOM DISS. OXYGEN (mg/L)	6.8	0.0
SEDIMENT: % ORGANIC MATTER		

LAKE TYPE: A natural lake.

SUMMER THERMAL STRATIFICATION: YES X NO ___ WEAK ___

IF YES, VOLUME OF HYPOLIMNION 241,000 (m^3) THERMOCLINE DEPTH 5.5 (m)

CHEMICAL: (mg/L unless indicated otherwise) LAKE: Beaver Lake

	WINTER		SUMMER		
DATE	14 Feb 1985		5 SEP 1984		
DEPTH (M)	4.5	9.0	2.0	6.0	10.0
pH (UNITS)	6.8	6.7	7.1	6.6	6.7
ALKALINITY (I. P.)	12.3	13.2	13.1	12.5	16.4
ALKALINITY (F.E.P.)	13.8	14.7	14.7	14.2	18.0
NITRITE+NITRATE NITROGEN					
TOTAL KJELDAHL NITROGEN					
TOTAL PHOSPHORUS	0.022	0.013	<.001	.004	<.001
SPEC. CONDUCT. (µMhos/cm)	114.3	112.6	83.7	80.4	87.6
APPARENT COLOR (UNITS)	30	30	35	40	50
TRUE COLOR (440 nm)(UNITS)	46	38			
MAGNESIUM			.91		
CALCIUM			5.4		
SODIUM			7		
POTASSIUM			1.6		
CHLORIDE			10		10
TN : TP					
INORG-N : INORG-P					
[Mg+Ca] : [Na+K]			.73		
CALCITE SATURATION INDEX			2.4		

* = NOT DEFENSIBLE NR = NO RESULT

TROPHIC CLASSIFICATION: 1984

	D.O.	S.D.	PLANT ABUND.	CHL a	TOTAL PTS.	TROPHIC CLASS.
CLASSIFICATION POINTS:	6	2	3	1	12	EUTRO.

COMMENTS:

1. This lake was previously surveyed in 1977. There was no change in trophic status. Weed growth was not as dense as in 1977, but algal growth was greater and water clarity was less.

2. pH and alkalinity readings were greater in 1984.

NEW HAMPSHIRE WATER SUPPLY AND POLLUTION CONTROL COMMISSION

LAKE TROPHIC DATA

MORPHOMETRIC:

LAKE	Beaver Lake	LAKE AREA (HA)	54.07
TOWN	Derry	MAXIMUM DEPTH (M)	13.7
COUNTY	Rockingham	MEAN DEPTH (M)	4.8
RIVER BASIN	Merrimack	VOLUME (M^3)	2,614,000
LATITUDE	42° 54'N	MUD SURFACE AREA (HA)	126.40
LONGITUDE	71° 18'W	RELATIVE DEPTH	1.7
ELEVATION (FT)	290	SHORE CONFIGURATION	2.23
SHORE LENGTH (M)	5800	AREAL WATER LOAD (M/YR)	10.60
WATERSHED AREA (HA)	2792.2	FLUSHING RATE (YR^{-1})	5.1
% WATERSHED PONDED	0.01	PHOSPHORUS RETENTION COEFF.	0.45

BIOLOGICAL:

DATE		25 JUL 1985
DOM. PHYTOPLANKTON (% total) 1		Chrysosphaerella (30%)
2		Dinobryon/Anabaena(20%)
NUMBER OF ALGAL GENERA		12
SPECIES DIVERSITY		2.61
CHLOROPHYLL a (µg/L)		5.92
DOM. ZOOPLANKTON (% total) 1		Keratella (30%)
2		
ROTIFERS/LITER		76
MICROCRUSTACEA/LITER		29
TOTAL ZOOPLANK. CNTS (cells/L)		105
VASCULAR PLANT ABUNDANCE		Abundant
DOMINANT VASCULAR PLANTS 1		Potamogeton robbinsii
2		Potamogeton amplifolius
3		
SECCHI DISK TRANSPARENCY (M)		3.8
BOTTOM DISS. OXYGEN (mg/L)		0.1
SEDIMENT: % ORGANIC MATTER		

LAKE TYPE: A natural lake.

SUMMER THERMAL STRATIFICATION: YES X NO ____ WEAK ____

IF YES, VOLUME OF HYPOLIMNION 404,000 (m^3) THERMOCLINE DEPTH 4.3 (m)

CHEMICAL: (mg/L unless indicated otherwise) LAKE: Beaver Lake	WINTER		SUMMER		
DATE			25 JUL 1985		
DEPTH (M)			2.0	6.0	9.5
pH (UNITS)			7.5	6.8	6.8
ALKALINITY (I. P.)			13.6	13.9	17.6
ALKALINITY (F.E.P.)			15.3	15.6	19.1
NITRITE+NITRATE NITROGEN			<0.05		<0.05
TOTAL KJELDAHL NITROGEN			0.40		0.48
TOTAL PHOSPHORUS			0.012	0.024	0.024
SPEC. CONDUCT. (µMhos/cm)			121.0	119.0	123.4
APPARENT COLOR (UNITS)			25	25	35
TRUE COLOR (440 nm)(UNITS)			18	20	49
MAGNESIUM					
CALCIUM					
SODIUM					
POTASSIUM					
CHLORIDE			19		18
TN : TP			33		20
INORG-N : INORG-P					
[Mg+Ca] : [Na+K]					
CALCITE SATURATION INDEX					

* = NOT DEFENSIBLE NR = NO RESULT

TROPHIC CLASSIFICATION: 1985

	D.O.	S.D.	PLANT ABUND.	CHL a	TOTAL PTS.	TROPHIC CLASS.
CLASSIFICATION POINTS:	6	1	3	1	11	Eutro.

COMMENTS:
1. Beaver Lake was previously surveyed in 1977 and 1984. The plant survey was not repeated in 1985. The 1984 plant survey data is reported here.
2. Trophic classification has remained the same since 1977.
3. No winter sampling was conducted in 1986, since it was just done the previous year. The 1985 summer sampling was at the request of the town of Derry.

Table II-5

UNH Summer 1988 Lake LLMP Data

Parameter	Range	Average	Comments
Secchi disk(m)	3.0-4.9	3.9	similar to '86, '87 results lower than '85 results
Chlorophyll-a (mg/L)	2.3-11.3	5.4	
D.O. (mg/L)			anoxic below 5.5 m
Color(true)	29-40	37	
Total phosphorus (ppb)			
upper layer	8-43	19	
lower layer	15-183		
A.N.C. (mg/L F.E.P.)	11-17		values comprable to '85-'87
pH			
upper layer	6.5-7.4		
Conductivity (umhos/cm)	105-335		much greater than previous years

Algae - blue-green dominant (Oscillatoria)
golden-brown sub-dominant

Table II-6

UNH Summer 1988 Tributary LLMP Data

LLMP	Biology	pH (average)	Conductivity uhoms/cm (average)	TP ppb (average)
6	Cat-O-Brook	6.87	259.6	17.1
6A	Cat-O-Swamp	6.87	212.6	26.1
8	Comeau's Beach Brook	7.0	229.8	11.0
9	Manter Brook	6.8	152.3	15.4
9A	Jenny-Dickey Brook	6.8	171.4	28.6

CHAPTER III

III. PHYSICAL CHARACTERISTICS OF THE LAKE AND ITS WATERSHED.

A. Climate

Beaver Lake is located in Rockingham County, Derry, New Hampshire, which is approximately 46.7 Km (29 mi.) southeast of the capital city, Concord. Its geographical co-ordinates are 42° 54' N and 71° 18' W.

The climate of the region is characterized by moderately warm summers, cold snowy winters and ample rainfall. The Atlantic Ocean which lies approximately 24 miles to the east of Beaver Lake occassionally affects the area weather, but the region is more commonly influenced by air moving from the interior due to the prevailing northwesterly winds. Day to day variation in temperature is common, since the lake lies in the normal path of changing weather systems that alternately transport warmer air from the southerly direction and colder air from the north.

B. Temperature

The mean monthly temperature of the area is 7.8°C (46°F). The mean temperature of the coldest month, January, is -6°C (21°F) and the mean warmest temperature is 21°C (70°F) in July. Nights are very often cool and confortable even during the summer months (US Department of Agriculture SCS, and National Weather Service Office Concord, NH and US Department of Commerce, NOAA weather service station, Manchester, NH). The weather data for the study period is presented in Table III-1 listing the temperature, precipitation and evaporation monthly averages.

C. Precipitation

Precipitation in the Derry area averages 39.4 inches per year, including the water equivalent of snowfall (averages since 1895). Precipitation in this region is acidic. The snowfall seasonal total was 42.61 inches for the first sample year and 25.5 inches for the second. Snow is present usually from mid December to the end of March.

Table III-1

Weather Data for the Study Period

Month	Average Temperature (deg F)	Precipitation Total (inches)	Precipitation Mean Monthly (inches) (29 year study)	Evaporation Total (inches)
Nov 89	35.8	2.98	3.46	.22
Dec 89	11.9	.64	3.04	--
Jan 90	28.6	3.84	2.90	--
Feb 90	24.6	2.55	2.61	--
Mar 90	34.7	1.48	3.06	--
Apr 90	45.6	3.82	3.01	--
May 90	52.8	6.07	3.17	1.70
Jun 90	65.3	2.63	3.31	4.75
Jul 90	70.8	3.17	3.55	4.65
Aug 90	69.8	12.55	3.42	4.73
Sep 90	59.7	1.49	3.36	2.49
Oct 90	51.8	6.68	3.19	1.18
Nov 90	40.1	2.97	3.46	--
Dec 90	30.9	4.63	3.04	--
Jan 91	20.2	2.25	2.90	--
Feb 91	28.3	1.64	2.61	--
Mar 91	36.0	3.06	3.06	--
Apr 91	47.6	2.02	3.01	--
May 91	60.2	3.18	3.17	--
Jun 91	65.6	3.26	3.31	3.89
Jul 91	69.2	2.92	3.55	5.58
Aug 91	69.9	8.38	3.42	5.72

D. Geography

Beaver Lake lies within the seaboard lowland section of the New England province in the southeastern portion of the state. It is characterized by low, rolling hills that rise between 100 and 200 ft above the valleys. The highest point of the Merrimack Quadrangle, in which the watershed lies, is Warner Hill, on the eastern boundary of the Beaver Lake watershed.

The watershed lies entirely within the drainage basin for the Merrimack River which flows southerly in the western part of the quadrangle. Three other ponds lie within the Beaver Lake watershed: Adams Pond, Harrantis Pond and a small fire pond. However, none of these ponds was sampled by the Biology Bureau, due to either private ownership or size restrictions.

E. Geology

When considering the geology of an area it is important to remember that the majority of the earth's crust is undergoing constant recycling. The earth is estimated to be about 4,600 million years old, while the oldest rocks in NH can be traced back only to around 650 million years, placing them in the late Precambrian period. These rocks are classified as metamorphic, and it is upon their base that the Beaver Lake watershed lies.

The rocks within the Beaver Lake watershed originated approximately 355 million years ago, when most of central and southeastern New Hampshire was under a great inland sea. This sea became the recipient of large amounts of sand and mud, which was being eroded from the region's highlands and carried to the sea via rivers and streams. Hundreds of millions of years of this deposition resulted in a great sheet of sand and mud more than 20,000 feet thick at the bottom of the sea. The sea receeded about 290 million years ago, leaving the land dry and exposing the bulk of this erodite which was the precourser to the sedimentary rock of New Hampshire.

The rocks derived from these sediments became phyllites, which are micaeous rocks similiar to roofing slate, mica schists and quartz-mica schists. These newly formed rocks soon began the process of breaking down, being exposed to erosion by wind and rain activity. Geologic forces exerted on the eastern shore of the precontinent caused the land to undergo severe buckling and folding, creating weak spots in the crust. Magma rose up from the earth's core and invaded the newly formed folds and fractures. These occurrences formed pigmatite dikes with embedded quartz, feldspar and mica, which are common in the area.

Pressure and heat caused the sedimentary rocks to metamorphose into several different rock types. These can be broken down into different categories, depending on the foliation type, or banding of minerals within the rock, and grain type. Both of these characteristics depend on the original type of sedimentary material of which the rock was derived. Some of the prominant metamorphic rocks in NH are quartzites, schists, muscovite, garnet, chlorite, biotite, staurolite and silimanite.

The Beaver Lake watershed is situated on strata of what is known as the Merrimack group of bedrock in the state's current division.

This formation is believed to have originated in the Silurian period. The group is made up of the Berwick and Eliot formations, which are composed chiefly of granulites and schists, with some gneiss interspersed.

Approximately 275 million years ago there was another period of stress on the earth's crust, causing more fractures and allowing for further intrusion of magma. This magma changed the composition of the strata to produce black, coarse-grained granite-like rock.

The next important geologic occurrence in the area began about 2 million years ago with the advent of the Great Ice Age. This had a tremendous effect on the topography and geology of northern United States. Starting in Labrador and Canada, ice spread out in all directions forming a massive glacier. It reached southeastern New Hampshire from the northwest, which is evident from scratches and grooves on rock surfaces and by the shape of hills carved or deposited by the glacier.

When the glacier began to melt, material picked up and carried in the bottom ice was redeposited on the bedrock, forming hardpan or till. The ice-laid till consists of unsorted fine, medium and large particles. This till, combined with glacial outwash, dammed the preglacial streams to form the many lakes, ponds and marshes common in the state. As the glacier receded and the weight of the ice was removed, the land slowly rose. Sea level dropped and the estuaries that were formed now drained. The streams and rivers resumed the erosion of the newly exposed land.

A map of the bedrock geology of the Beaver Lake watershed is presented in Figure III-1.

BEAVER LAKE WATERSHED: BEDROCK GEOLOGY

SCALE: 1 in. = 1750 ft.

FEET

2000 1000 0 2000 4000

Data sources: Geology - from Interim Geologic Map of New Hampshire, 1986, source scale 1:250,000.
Watershed divides compiled and digitized at Water Resources Division, DES, and at Office of State Planning; source scale 1:24,000.
All other features from USGS Digital Line Graph data, source scale 1:24,000.

Prepared at New Hampshire Office of State Planning, March 1992

D1m - Two-mica granite of northern and southeastern NE

OZb - Berwick Formation

OZbu - Berwick Formation, Upper (?) Member

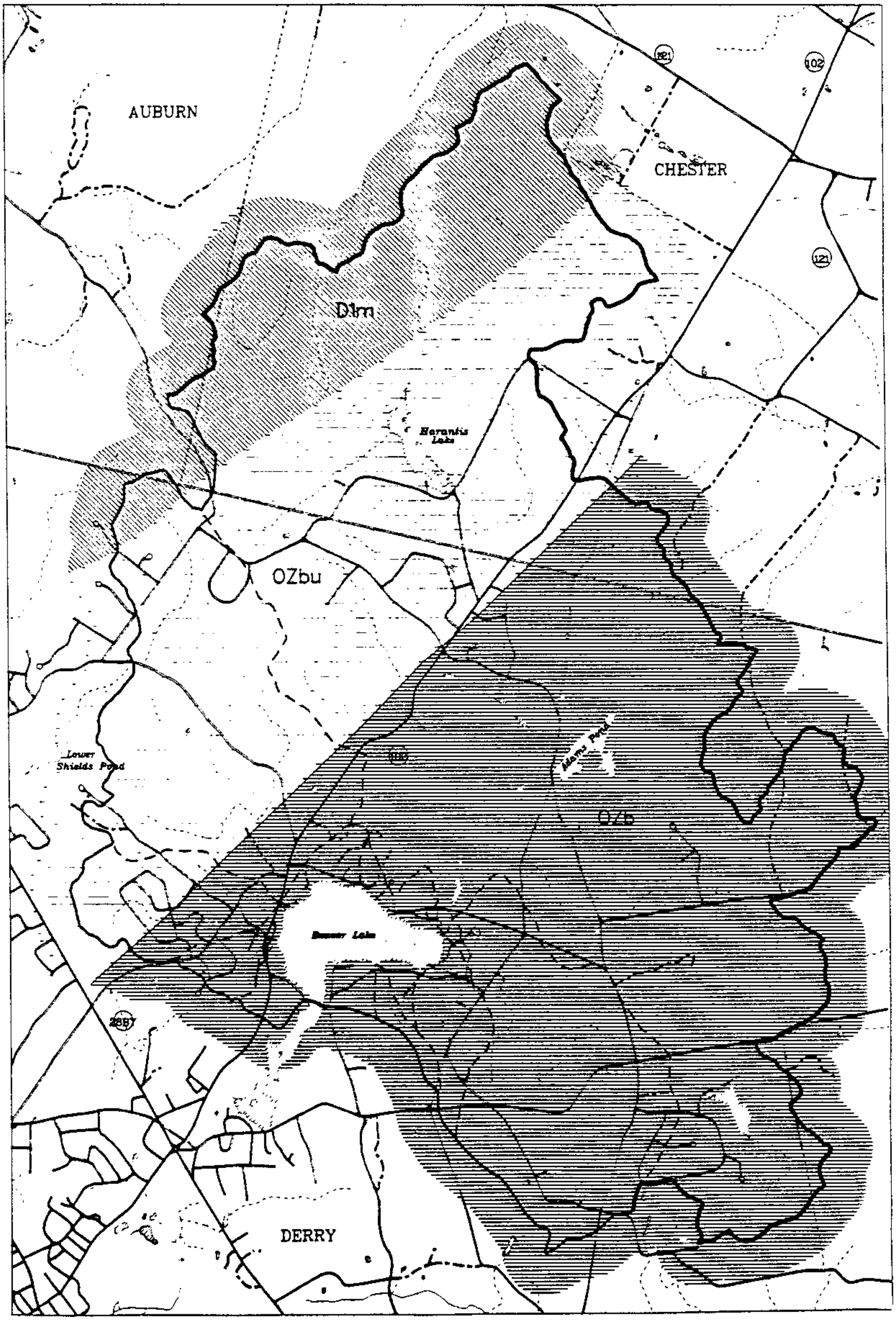
Merrimack River watershed boundary

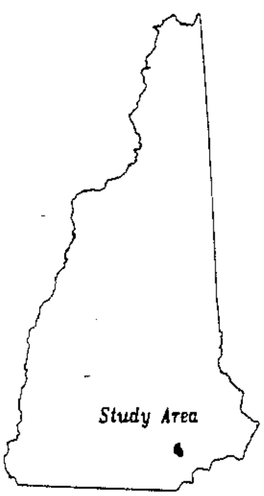
Beaver Lake watershed boundary

Subwatershed boundaries

Geological contact

N





NEW HAMPSHIRE GRANIT

Geographically Referenced Analysis and Information Transfer System

Natural lakes in the region are relatively young geological features and are all due to the modification of the land's surface by the ice sheet.

Many of the natural lakes in the surrounding area include:

1. Rock basin lakes formed in depressions in valleys scoured out and overdeepened at favorable places by advancing ice.

2. Drift-dammed lakes formed either during ice advance or recession, by deposition of more drift in one part of a valley than in another.

3. Kettle hole lakes rest in depressions left by the melting of ice blocks. These depressions are surrounded or covered by outwash material which was deposited by streams of meltwater from the waning glacier or its remnants. Many of these lakes and ponds are quite small. However, there are a few which are greater than 100 acres. Kettle Hole Lakes always occur in association with meltwater deposits rather than with till. Many of these lakes tend to be shallow, and have low, sandy or gravelly shores.

F. Soils

Overlying the bedrock are the soils of the region, the direct results of erosion and surficial deposition occurring since the retreat of the glacial ice sheet. They tend to reflect the underlying geologic types from which they were derived. The properties of these deposits, and the soils which have developed from them, affect the hydrology of the area. The most important aspects as far as the hydrology is concerned include drainage and erodability. Drainage refers to the soil's ability to absorb water, while erodability refers to how easily the soil is eroded by water moving over its surface. In general, the better a soil's internal drainage, the lower is its potential for erosion, though occurrence and slope may influence erodability more than the soils drainage properties.

The Beaver Lake watershed lies in an area in which the soils have been described as well drained to very poorly drained soils on glacial till, with gently rolling or nearly level topography. The composition of the soils includes Canton, Hollis and Woodbridge types in the ratio of 45%, 25% and 10% respectively.

Canton type soils tend to be deep, well drained and formed over glacial till. Water drains through these soils at a moderate rate. These soils are suited for vegetable or fruit gardening, if well irrigated and managed, and are fair for forestry uses. The potential for wildlife habitat is good for both open land areas and wooded. These soils also have few limitations for developmental purposes, as attested by the recent rash of new homes and buildings in the area.

The Hollis type of soil can be excessively drained, and is believed to have formed in a thin layer of till over bedrock. This bedrock causes the vertical migration of water to be restricted. Crops on these soils may require irrigation in times of low precipitation, and the soil is considered a poor candidate for forestry due to the closeness of the bedrock. It is also considered poor for both wooded and openland wildlife habitat, and presents severe limitations for development.

Woodbridge soils are characterized as deep, moderately well drained and formed in compact glacial till. This compact till has contributed to the existence of a distinct hardpan layer which is located approximately two feet below the grounds surface, and forms a perched water table during the wet seasons. Water does move through this hardpan layer, but slowly.

These sites are considered prime farmland if they are non-stoney and occur on gentle slopes, but care must be taken to prevent erosion. Good farming uses for them include hay and pasture land, corn silage, and vegetable or small fruit production. Woodbridge soils also offer chance for good productivity for forestry practices and good wildlife habitat both in open and wooded areas. However, the presence of a high water table and hard pan layer is an important concern when considering these for development.

A soils map for the Beaver Lake watershed is presented in Figure III-2.

G. Land Cover & Land Use Regulation

Land use within the watershed is extremely important in determining areas which are potential nutrient contributors to a lake system. Certain uses, such as agricultural or urban, can accelerate lake eutrophication.

The entire Beaver Lake watershed has been zoned for single family residential use. However, the zoned use and the actual use do not coincide. This is definately the case in the Beaver Lake watershed. Derry is an old farming town, and as such any area is designated as permissible for farming.

BEAVER LAKE WATERSHED: SOILS

Limitations for septic systems:

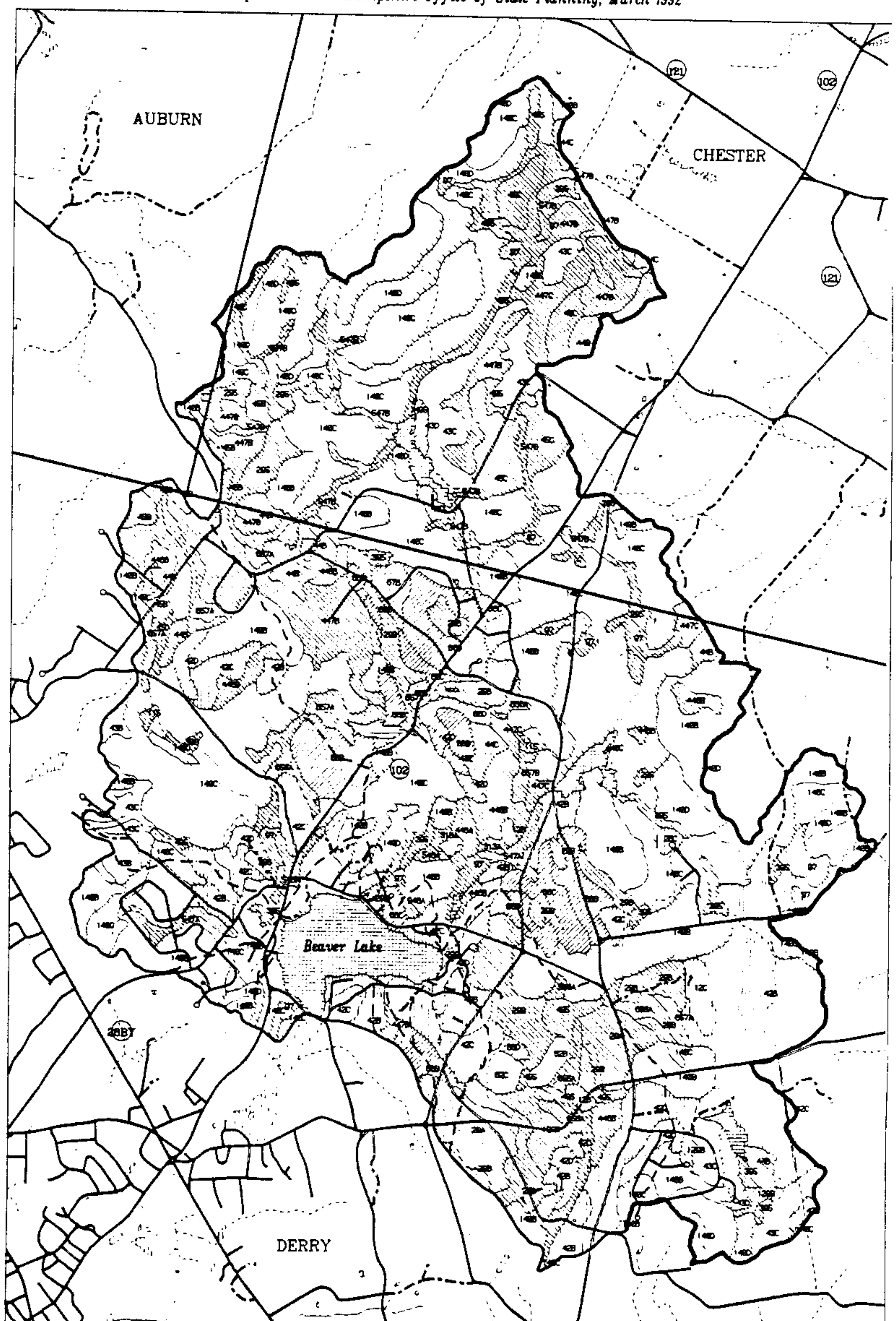
- *Severe – wetness (ponding or high water table)*
- *Severe – bedrock at 20" or less*
- *Severe – slope*
- *Severe – slow percolation*
- *Severe – poor filter*
- *Moderate – contains large stones*
- *Moderate – slope*
- *Slight or unclassified*

SCALE: 1 in. = 1750 ft.

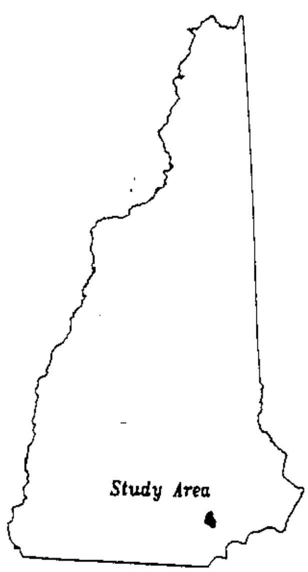
FEET
2000 1000 0 2000 4000

Data sources: *Soils – unpublished Rockingham Co. soil survey (SCS), digitized at 1:24,000 at Complex Systems Research Center, Durham, NH. Watershed divides compiled and digitized at Water Resources Division, DES, and at Office of State Planning; source scale 1:24,000. All other features from USGS Digital Line Graph data, source scale 1:24,000.*

Prepared at New Hampshire Office of State Planning, March 1992



N



NEW HAMPSHIRE
GRANIT
Geographically Referenced Analysis and Information Transfer System

The town has been undergoing much development in the past forty years and the emphasis has shifted from a farming/mill community to one largely based on industry. Table III-2 lists the towns in the Beaver Lake Watershed and shows the historic change of land use by percent.

A breakdown of the current land uses in the area was conducted utilizing the most current aerial photographs available. Table III-3 outlines characteristics of the cover types and the percent occurance of each within the watershed.

As the table indicates, the predominant land cover type within the Beaver Lake watershed is forest/abandoned field, encompassing 70.1%. This land use is not expected to be an excessive nutrient contributor to the lake. The next two largest categories of land use in the watershed are residential and agricultural, accounting for 14.1% and 12.2% of the area respectively. These types of land usage have long been known to impact lake systems through the addition of nutrients. Sources of nutrients from these land uses include failed septic systems and fertilizer runoff.

Open water areas take up 2.4% of the area, and the remaining categories of wetland and tree farm/orchard each amass .6% of the total. These areas are not suspect as major nutrient contributors.

Table III-2

Historic Land Use Change

Town of Chester 16,196 Acres			Town of Derry 23,001 Acres		
Use	1950's	1970's	Use	1950's	1970's
Agr.	13.9%	10.8%	Agr.	20%	11.2%
Idle	3.1%	1.8%	Idle	5.2%	4.8%
For.	83.1%	85.7%	For	70%	67.4%
Dev.	0	.3	Dev.	3.3%	15.3%
Other	0	0	Other	1.4%	1.2%

From Office of State Planning

Table III-3

Land Use Cover Types, Characteristics and Occurrence Within the Beaver Lake Watershed

Cover Type	Characteristic	Acres	% Occurrence
Forest/Abandoned field	land has no apparent development or active agricultural usage	4831.3	70.1
Residential	residential usage zones single family dwelling	974.4	14.1
Agricultural	Active agricultural usage (tilled land, grazing, crops)	840.9	12.2
Open water		165.2	2.4
Tree Farm/Orchard	Active agricultural/ horticultural usage	43.5	.6
Wetland	Marsh, swamp, bog or other poorly drained lowland	41.4	.6

CHAPTER IV

IV. MONITORING PROGRAM, SCOPE & METHODOLOGY

A. Morphometry

Beaver Lake, like many of New Hampshire's natural lakes, owes its geomorphological origin as a glacial ice scour lake. It lies within the Town of Derry, N.H. The watershed is split between the Towns of Derry and Chester with 76.4% lying in Derry and 23.6% in Chester.

Beaver Lake is a north temperate dimictic lake (lake that has complete vertical mixing twice a year) with a shore length of 5800m (19029 ft) and an area of 54.07 ha (133.6 acres, NHSPP, 1964). The area was taken from the NH State Planning Project Publication. The lake's mean depth is 4.8m (15.8 ft), and the maximum depth is 13.7 m (44.95 ft). It lies approximately 88.4m (290 ft) above sea level. The total volume of the lake is 2,614,000 m^3. The watershed area which drains into the lake is 2792.2 ha (689.7 acres). The physical morphometry of the lake is summarized in Table IV-1. A recent bathymetric map portraying the depth contours appears in Figure IV-1. Data to construct this map was obtained by conducting a series of transects with a digital fathometer. Lake volume was calculated by summing the volumes between of successive contours using in-house software (Martin, 1986). The watershed boundary was drawn from a USGS topographic map and its area was determined planimetrically.

Table IV-1

Physical Morphometry Summary

LAKE	Beaver Lake	LAKE AREA (HA)	54.07
TOWN	Derry	MAXIMUM DEPTH (M)	13.7
COUNTY	Rockingham	MEAN DEPTH (M)	4.8
RIVER BASIN	Merrimack	VOLUME (M^3)	2,614,000
LATITUDE	43° 54'N	MUD SURFACE AREA (HA)	126.40
LONGITUDE	71° 18'W	RELATIVE DEPTH	1.7
ELEVATION (FT)	290	SHORE CONFIGURATION	2.23
SHORE LENGTH (M)	5800	AREAL WATER LOAD (M/YR)	10.60
WATERSHED AREA (HA)	2792.2	FLUSHING RATE (YR^{-1})	5.1
% WATERSHED PONDED	0.01	PHOSPHORUS RETENTION COEFF.	0.45

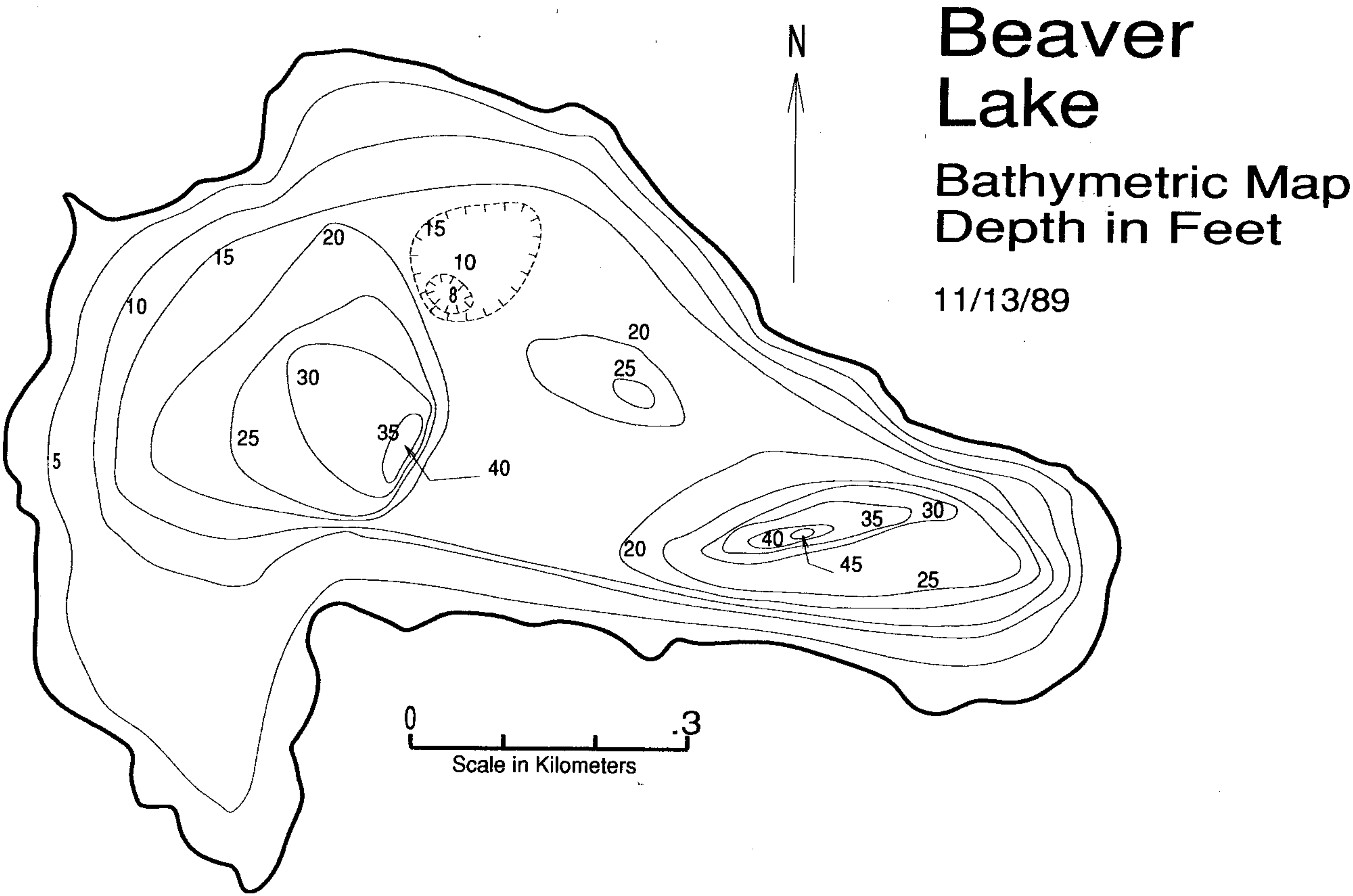


Figure IV-1. Beaver Lake Bathymetric Map

B. Station Locations & Descriptions

Sampling locations, depicted in Figure IV-2, were chosen to include all inlets and outlets. Table IV-2 presents a brief description of each tributary sample station. The lake quality monitoring station was established at the deepest part of Beaver Lake (13.7 m) and sampled at three depths, 2.0, 5.0 and 10.0m during the stratified season and at 1/3 and 2/3 of the water depth during the unstratified season. Lake quality, in general, varied with depth, reflecting different density layers achieved in dimictic lakes.

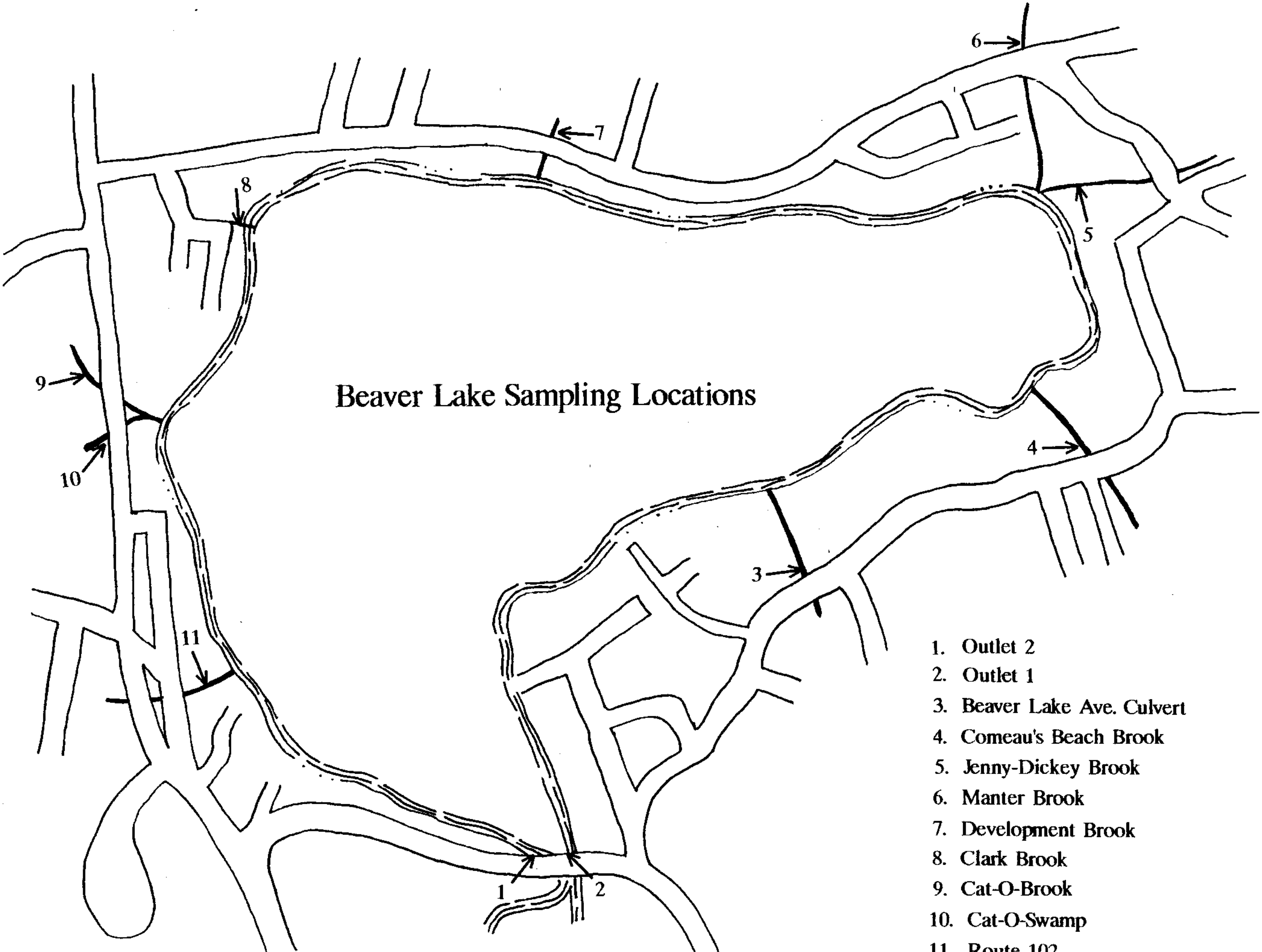
The lake has four major tributaries, several minor ones and two outlets. They are listed here in order of descending water contribution. The major tributary, Manter Brook, feeds into the lake at the northeast corner and receives drainage from Adams Pond and Harrantis Pond. The tributary passes through farmland before draining into Beaver Lake.

The next largest contributor in terms of volume is Jenny-Dickey Brook. This brook enters the lake from the east and receives the outfall from a small fire pond. The brook drains through a largely residential area.

Cat-O-Brook enters the pond from the Northwest. It drains wetlands upstream and passes through farmland before passing through residential areas on its way to the lake. Directly adjacent to this tributary is Cat-O-Swamp, which also drains a swamp upstream, travels through a residential area and then back through a wetland before merging with Cat-O-Brook at its mouth.

The minor tributaries are also listed in order of descending contributing volume. Rte. 102 tributary enters Beaver Lake from the west and receives drainage from a residential area. Comeau's Beach Brook enters from the east and drains mostly residential neighborhoods. Development Brook enters from the north and, as its name suggests, drains a new development on the lake's shore and a small retention pond. Beaver Lake Ave Culvert (B.L.A.C.) enters the pond from the Southeast and collects runoff from a largely residential area. Finally, Clark Brook joins the lake at the northwest corner and drains a residential area. The outlets of the lake are adjacent to one another and exit the lake from the southeast. They drain into a large wetland before passing through a golf course and then through the town.

Beaver Lake Sampling Locations



1. Outlet 2
2. Outlet 1
3. Beaver Lake Ave. Culvert
4. Comeau's Beach Brook
5. Jenny-Dickey Brook
6. Manter Brook
7. Development Brook
8. Clark Brook
9. Cat-O-Brook
10. Cat-O-Swamp
11. Route 102

Table IV-2
Sampling Site Description

Site Number	Site Name	Location
1	Outlet 2	crosses under Pond Road approx. 1/2 mile from junction w/Rte. 102
2	Outlet 1	adjacent to outlet 2; larger of the outlets
3	Beaver Lake Avenue (B.L.A.C.)	passes under Beaver Lake Avenue
4	Comeau's Beach Brook	passes under Beaver Lake Avenue adjacent to Comeau's Beach
5	Jenny-Dickey Brook	passes under North Shore Road adjacent to Beaver Lake Park
6	Manter Brook	at junction of Beaver Lake Road and North Shore Road
7	Development Brook	under North Shore Road, next to development
8	Clark Brook	runs along the Clark's house on Mckinley Ave.
9	Cat-O-Brook	passes through Jake's Auto Body parking lot off Route 102
10	Cat-O-Swamp	adjacent to Cat-O-Brook on Route 102 drains the swamp and joins with Cat-O-Brook before entering the lake
11	Route 102	drains under Route 102.

C. Lake Field Procedures

The lake station was sampled monthly from November, 1989 through January, 1991. Temperature and dissolved oxygen were measured at one meter intervals using a YSI model 50, 54, or 57 oxygen meter during open water periods, and hypolimnetic dissolved oxygen was measured using the Winkler method (azide modification) during the ice-cover period. Temperature was recorded to the nearest 0.1 degrees Celsius. Dissolved oxygen was recorded to the nearest 0.1 mg/L.

Water samples were collected with a Wildco Kemmerer water sampler. Samples were preserved for nutrient analysis when appropriate. All samples were stored in a cooler and returned to the State Water Quality Laboratory and the Limnology Center in Concord, New Hampshire for analysis.

Transparency was measured to the nearest 0.1 meter using a 20 cm. diameter Secchi disk with alternate black and white quadrants. Net phytoplankton and zooplankton were collected by vertically hauling a Wisconsin 80 micron-mesh net from the thermocline. One sample was preserved in the field with Lugol's solution to determine plankton abundance. A second sample was returned live to aid in identification. Wholewater phytoplankton samples for inverted microscope density counts and chlorophyll-a analyses were collected with an integrated sampler (weighted tube, 1"ID) or by compositing several discrete samples at successive depths from the surface to the mid-thermocline.

D. Stream Field Procedures

The tributary stations were sampled at least every two weeks from October, 1989 through January, 1991. Staff gage measurements were recorded each sampling trip. Flow measurements were taken using a Marsh McBirney flowmeter to determine discharge in cubic feet per second (C.F.S.) at each station. Discharges were measured at least two times per month and weekly when possible. Samples were collected by dipping laboratory bottles to mid-depth at mid-stream in flowing water. Table IV-3 summarizes the sampling parameters for the Beaver Lake Study.

E. Groundwater Seepage

Groundwater seepage into the lake was measured at least 3 times a month during the growing season. Seepage meters were constructed using the top and

Table IV-3

Sampling parameters for Beaver Lake Study.

Parameter	Location
Temperature/Dissolved Oxygen	lake
pH	lake and streams
Acid Neutralizing Capacity	lake and streams
Specific Conductance	lake and streams
Chlorides	lake and streams
Sulfates	lake and streams
Color	lake and streams
Total Phosphorus	lake and streams
Nitrate Nitrogen	lake and streams
Total Kjeldahl Nitrogen	lake and streams
Plankton	lake
Chlorophyll-a	lake
Transparency	lake
Turbidity	streams

Freezedryer
for
Walter

bottom thirds of 55 gallon drums. A cork with rigid tubing was inserted into the flat portion and left in place. Seepage measurements were collected by attaching a seepage bag to this cork. Seepage bags were constructed of flexible tubing (which fits over the open end of rigid tubing in the seepage meter cork) attached to a cork with a whirl bag connected to it. Prior to attachment to the seepage meter 50mL of water was placed in the bag to record possible negative flow. After one hour, the plastic whirl bags were removed, and amount of seepage was measured and recorded. A diagram of the seepage meter appears in Figure IV-3.

An interstitial pore water sampler (IPWS) was used to collect groundwater for chemical analysis. I.P.W.S. samples were analyzed for TP, conductivity and chlorides. The samples were collected at least two times per month for the duration of the growing season. See Figure IV-4 for a description of this specialized sampler.

Groundwater was also sampled by collecting water from houses with shallow dug wells around the periphery of the lake. Locations of these samplings sites is given in Figure IV-5.

F. <u>Sediment Analysis</u>

A sediment profile map was constructed by drilling holes in the ice along several transects and lowering stainless steel sediment rods (designed by DES personnel) into the lake. Measurements were taken of water depth, sand layer depth (if present) and depth of fine silty muck to the refusal layer. Sediment differences can be determined by the feel of the rod as it is rotated into the sediments. Sandy layers conduct a gritty feeling to the hand, while mucky layers are generally smooth feeling. The rods are 10' long, and designed so that additional lengths can be added if needed to achieve maximum depth. The sediment map appears in Figure IV-6.

Sediment cores were taken at the deep spot of the lake using a Wildco KB^{tm} coring device. Samples were analyzed for recoverable Al, Cd, Cu, Fe, Pb, Mg, Zn and P. A complete description of sediment analysis techniques and results appears in Chapter IX.

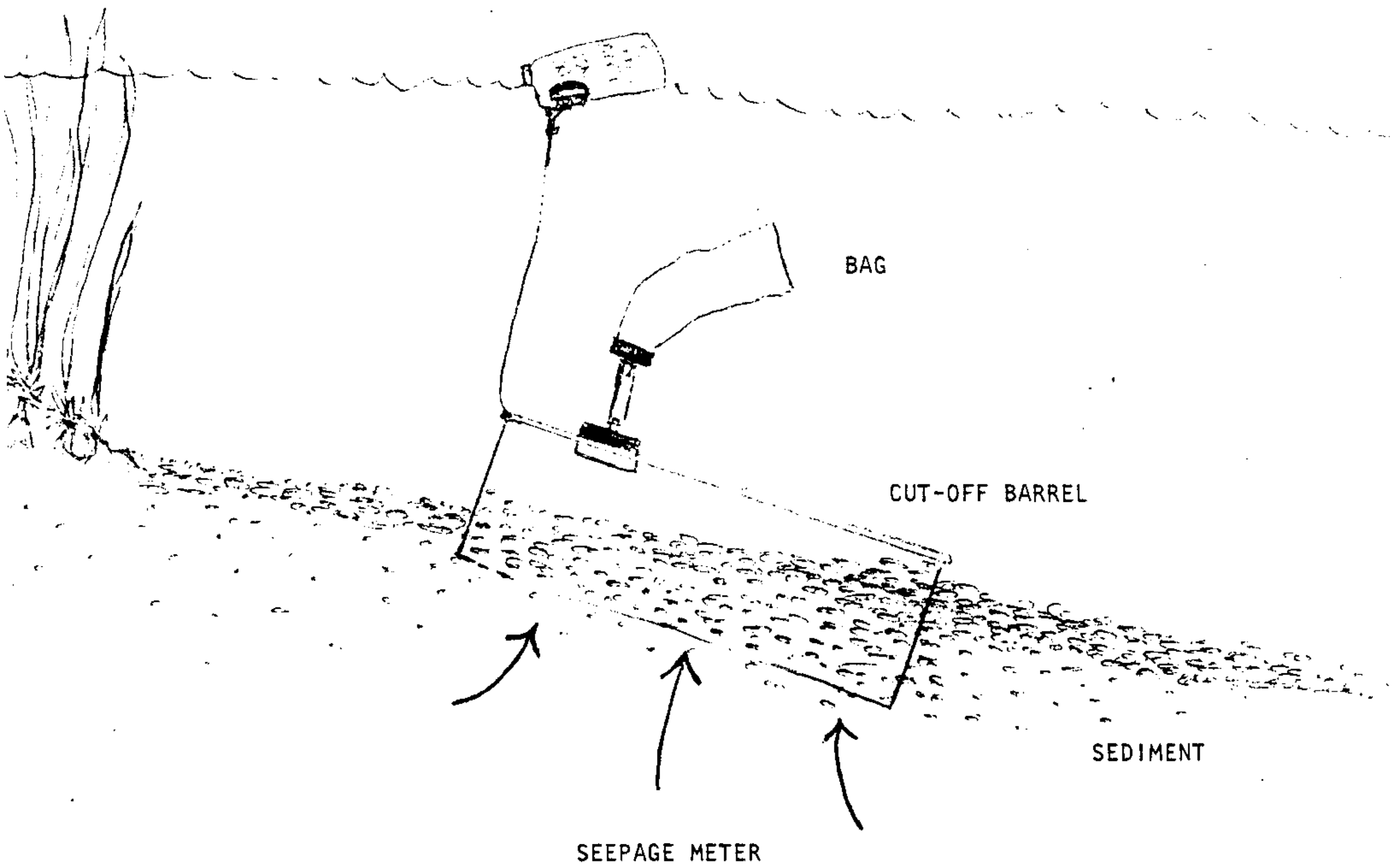


Figure IV-3. Seepage Meter Diagram

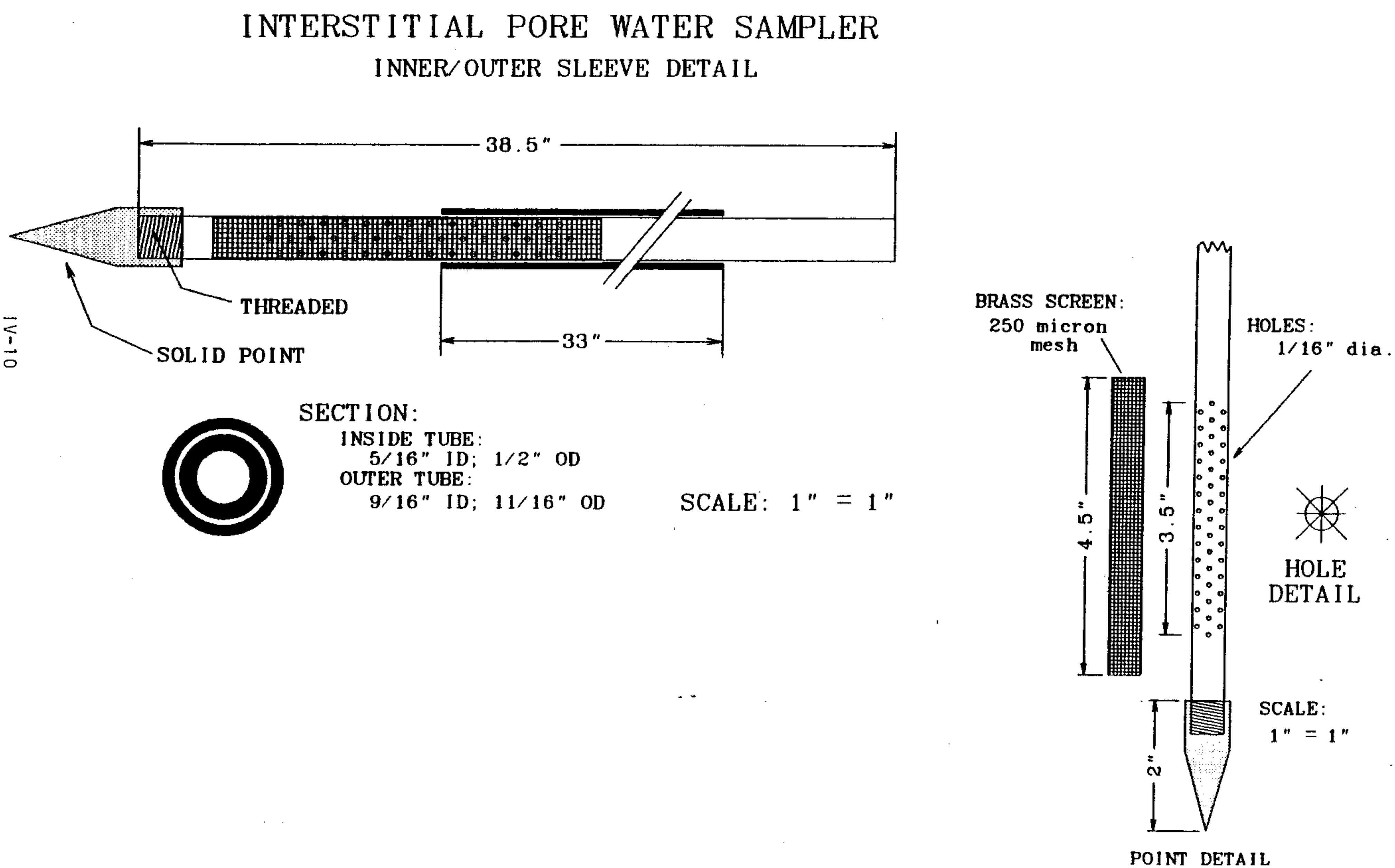


Figure IV-4. I.P.W.S. Sampling Apparatus

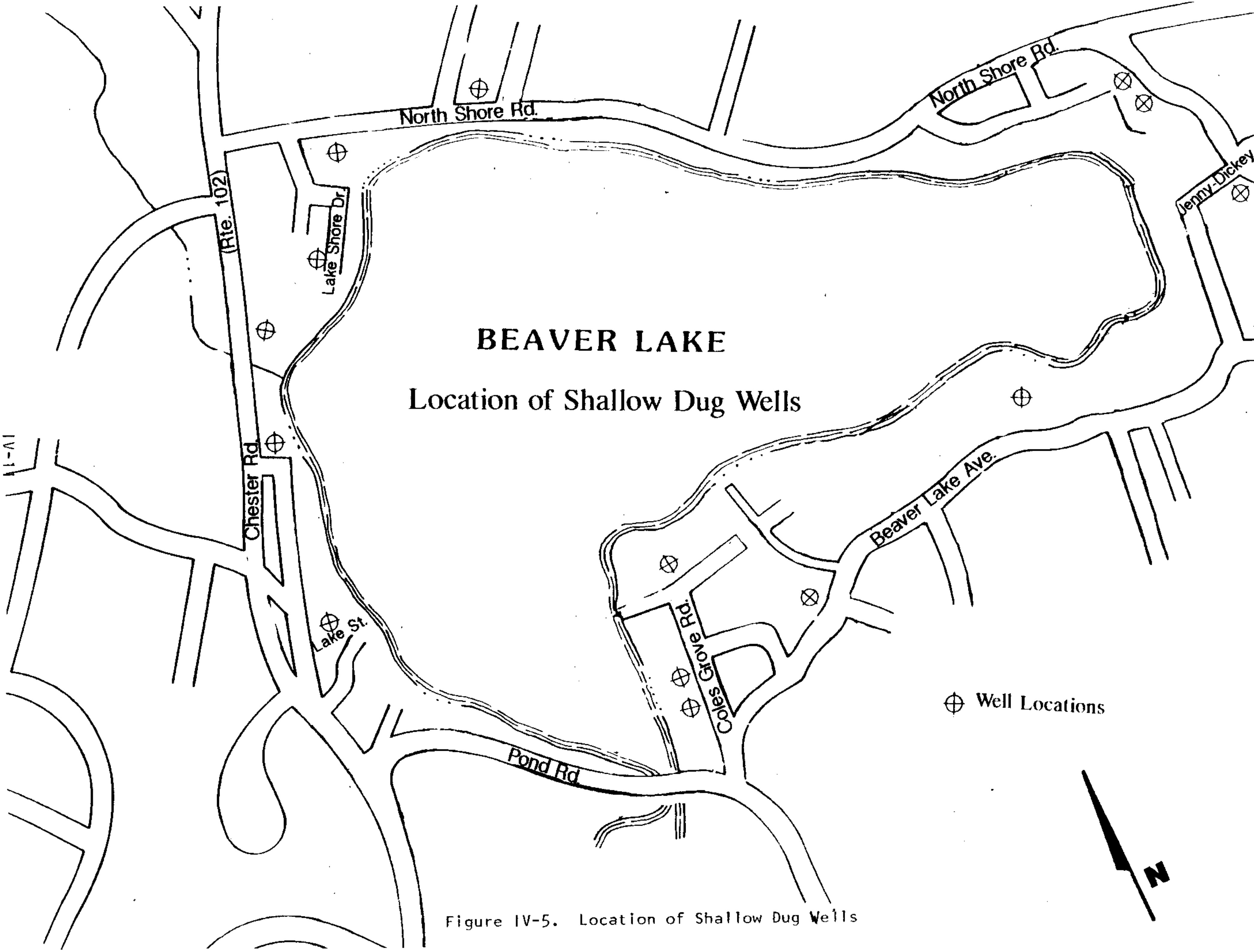


Figure IV-5. Location of Shallow Dug Wells

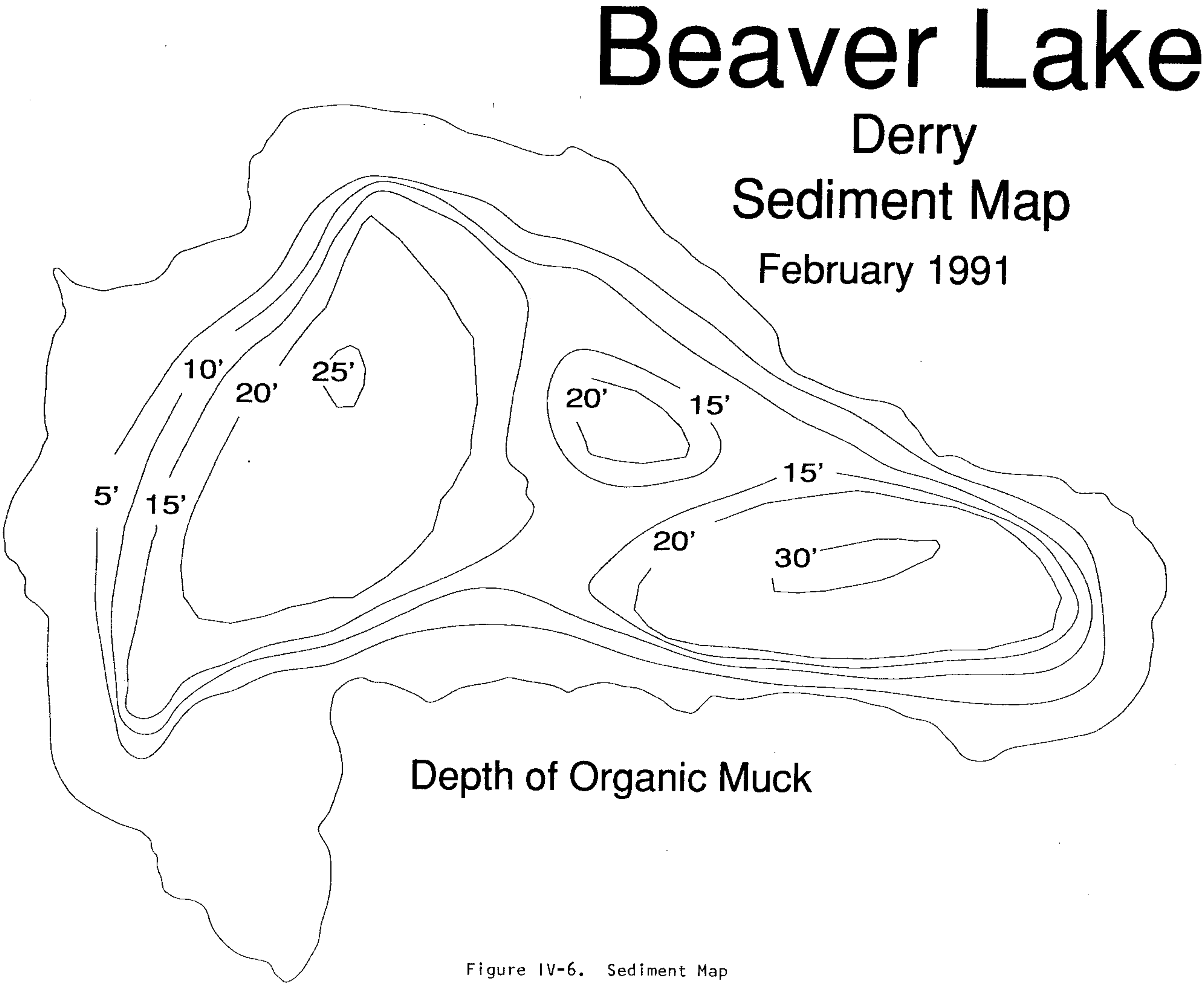


Figure IV-6. Sediment Map

G. Laboratory Methodology

1. Chemical and Physical

Table IV-4 presents the laboratory methods utilized for chemical and physical parameters. Acid Neutralizing Capacity, pH, specific conductance, and color analyses were performed by biologists in the Limnology Center. Chloride, sulfate, total phosphorus, nitrate nitrogen, and total Kjeldahl nitrogen analyses were performed by the Laboratory Services Unit. Both the Limnology Center and the Laboratory Services Unit are EPA inspected with approved quality assurance and quality control programs.

2. Biological

Table IV-4 also presents the laboratory methodology used for biological parameters. All analyses were performed by Biologists in the Limnology Center. Phytoplankton and zooplankton were identified to genus. Relative abundance was computed for net phytoplankton. Zooplankton and phytoplankton densities were also determined. Both chlorophyll-a content and plankton counts were determined following procedures outlined in Standard Methods 18th Edition (1992, Storet #10200). Chlorophyll-a measurements, and actual cell densities were used to determine algal biomass.

Table IV-4

Laboratory parameter and method used for analysis.

Parameter	Method
pH	Electrometric
Acid Neutralizing Capacity	Titration, Electrometric, Granplot
Total Phosphorus	Colorimetric, persulfate digestion
Specific Conductance	Wheatstone bridge type meter
Apparent Color	Colorimetric, Platinum-cobalt
Chloride	Ion Chromatography
Sulfate	Ion Chromatography
Nitrate Nitrogen	Ion Chromatography
Total Kjeldahl Nitrogen	Auto-Analyzer with block digester
Net phytoplankton (relative abundance)	Phase Contrast Microscopy, Sedgwick-Rafter Cell
Zooplankton (density counts)	Phase Contrast Microscopy, Sedgwick-Rafter Cell
Wholewater phytoplankton	Inverted Microscope, settling chamber
Chlorophyll-*a*	Spectrophotometric, Trichromatic

Laboratory Service Unit Method Numbers

Analysis	EPA Methods	
Chloride	300.0	*PQL 2mg/L
Nitrate-Nitrogen	300.0	PQL 0.05mg/L
TKN-Nitrogen	351.2	PQL 0.10mg/L
Total-Phosphorus	365.2	PQL 0.001mg/L
Sulfates - IC	300.0	Detection limit 0.5mg/L
Total Coliform MF,MPN	SM-909A, 908A	
Fecal Coliform MF,MPN	SM-909C, 908C	

*PQL= Practical Quantitation Level

V. WATER QUALITY

A. Temperature

Beaver Lake has a typical thermal stratification cycle for a north temperate dimictic lake. Stratification developed by early May and remained until late October, with the depth of the thermocline becoming characteristically progressively deeper as the summer wore on. Beaver Lake had isothermal conditions during spring and fall overturn, and was typically inversely stratified during ice-cover periods. A typical summer D.O./Temp profile appears in Figure V-1. Additional profiles and raw data are compiled in Appendices V-1 and V-2.

B. Dissolved Oxygen

Dissolved oxygen was measured in the field during open water seasons, and is described in the on-site measurement section (IV-C). The Winkler Titration method was used during ice cover. Dissolved oxygen is important to oxidation-reduction reactions and is necessary in order to sustain aerobic aquatic life from bacteria to fish.

The hypolimnion of Beaver Lake exhibited anoxic (low dissolved oxygen) conditions from early July through the fall turnover. During this time the oxygen deficit was apparent from 7 meters to the bottom of the lake. Several factors contribute to hypolimnetic anoxia, including strong thermal stratification and various biological and chemical interactions that occur in the hypolimnion. Significant biological utilizers of dissolved oxygen include the population of decomposing bacteria that live at the lake's sediment interface. These bacteria break down all organic material that falls to the benthos and in the process utilize available oxygen and liberate carbon dioxide.

Hypolimnetic anoxia is significant in Beaver Lake because it allows for the release of phosphorus from bottom sediments into the overlying water layer (internal loading). This liberated phosphorus, being a limiting nutrient for plant life, may cause spring and fall planktonic blooms in the lake.

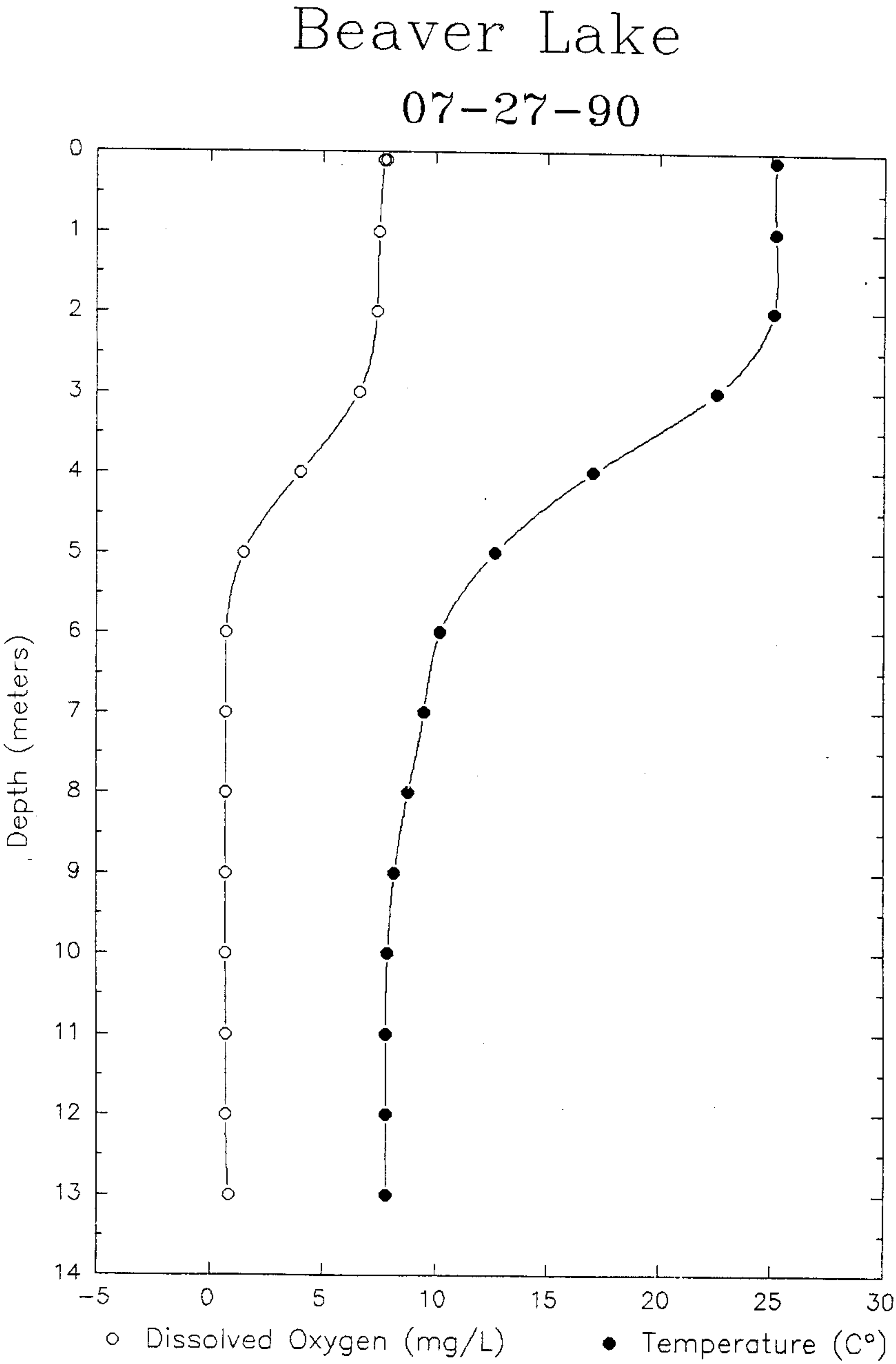


Figure V-1. Dissolved Oxygen/Temperature Profile

C. pH and Acid Neutralization Capacity (ANC)

The hydrogen ion concentration or pH, is defined as the negative base 10 logarithm of the hydrogen ion activity in moles per liter. The pH scale ranges from 0-14 with 7 being a neutral value. 'Pure' water has a pH of seven which means it contains 1×10^{-7} moles per liter of hydrogen ions. The pH scale is logarithmic, therefore each unit change is a tenfold change. A pH of 5 is ten times more acidic than a pH of 6. "Natural" rain water at equilibrium with the atmosphere has a pH of 5.6. Most New Hampshire lakes are slightly acidic, with pH values between 6 and 7. When the pH value falls between 6 and 5.5 the waters are considered endangered, lakes with pH's from 5.4 to 5 are considered in the critical range, and below this point lakes are considered acidified.

One of the most important reactions occurring in water, and one which affects pH, is that of dissolved carbon dioxide; represented by the following equilibrium equation:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + CO_3^=$$

When phytoplankton consume CO_2 during daylight hours in photosynthesis, the equilibrium shifts toward the left. This results in fewer free H^+ ions, causing a decrease in H+ ion concentration and thus an increase in pH. It is, therefore, not uncommon to find high pH values associated with an algal bloom.

The Fisher Accumet pH meter Model 825 mp or the Beckman pH meter was used to measure pH to the nearest 0.05 pH units.

The ANC of water is the capacity of water to accept protons, or, in other words, to neutralize hydrogen ions. It is primarily a measure of the concentration of carbonates, bicarbonates, and hydroxides in the water. New Hampshire lake waters are generally low in ANC (ANC's range from 2 to 20 mg/L as $CaCO_3$). This is due in part to the State's granitic bedrock which contains few of these compounds. As a result, N.H lakes have a poor buffering capacity, and thus are more susceptible to some ionic pollutants than higher ANC lakes.

Acid neutralizing capacity was determined potentiometrically by titrating a volume of sample with standard acid to predetermined pH values. Raw chemistry data is presented in Appendix V-3.

a. pH and ANC Tributary Data

Values in tributary pH data ranged from a low of 5.92 at B.L.A.C. tributary to a high of 7.67 at the Rte. 102 tributary (see Table V-1, Figure V-2).

The lowest true mean pH for the study period occurred at the B.L.A.C. tributary and was 6.50. The highest true mean pH was 7.51 obtained from the Rte. 102 tributary. In the majority of streams the highest mean seasonal pH occurred in the summer as expected, when productivity is at its highest. Aquatic algae and plants are consuming carbon dioxide at this time as they carry on photosynthesis. This tends to increase the pH of the waters. The observed high and low values were well within expected values and show no problems from acid rain.

Acid neutralizing capacity values for the tributaries are presented in Table V-2. Figure V-3 depicts the tributary A.N.C. range and mean values for the study period. Both the lowest mean and the lowest median ANC values were recorded at the B.L.A.C. tributary. The highest mean and median ANC (50.2 mg/L) were obtained for the Cat-O-Swamp tributary.

b. pH and ANC Lake Data

Biological activities can influence the pH of the water. Planktonic photosynthesis removes carbon dioxide from the lake, causing the pH to rise. For this reason the photic zone tends to have higher pH values than the underlying layers, and the highest values are recorded during the summer when phytoplankton populations are at their maximum levels. Values measured during spring and fall overturn are usually similar thoughout the water column.

In general, pH values from Beaver Lake follow this trend. During the stratified months the true mean pH was highest in the epilimnion where photosynthesis was the greatest, and decreased progressively towards the bottom. The stratified season showed similar true mean pH's at both levels.

In contrast to pH, ANC values are inclined to be higher at the bottom of a lake. This is caused by the release of buffering materials from the lake sediments to the overlying waters. This trend can be seen during the stratified season of the Beaver Lake data (Table V-3). During the unstratified season the values were similar at both levels as would be expected.

Table V-1
True Mean Study Period and Seasonal pH
for Beaver Lake Tributaries

Station	Study Period Mean/Median		Winter	Spring	Summer	Fall
Outlet 1	6.92	7.25	7.07	6.64	7.55	7.28
Outlet 2	7.16	7.12	--	6.76	7.36	7.37
B.L.A.C.	6.50	6.47	5.92	6.49	--	6.75
Comeau's Beach Brook	7.23	7.20	6.98	7.27	7.44	7.05
Jenny-Dickey Brook	7.17	7.17	7.22	7.14	6.96	7.26
Manter Brook	6.70	6.64	6.72	6.74	6.73	6.59
Development Brook	7.03	6.62	6.43	6.55	7.52	--
Cat-O-Swamp	7.42	7.33	7.27	7.44	7.48	7.38
Cat-O-Brook	7.02	7.02	6.97	6.93	7.19	7.03
Clark Brook	6.77	6.75	6.24	6.75	--	7.01
Rte. 102	7.51	7.34	7.00	--	7.67	7.56

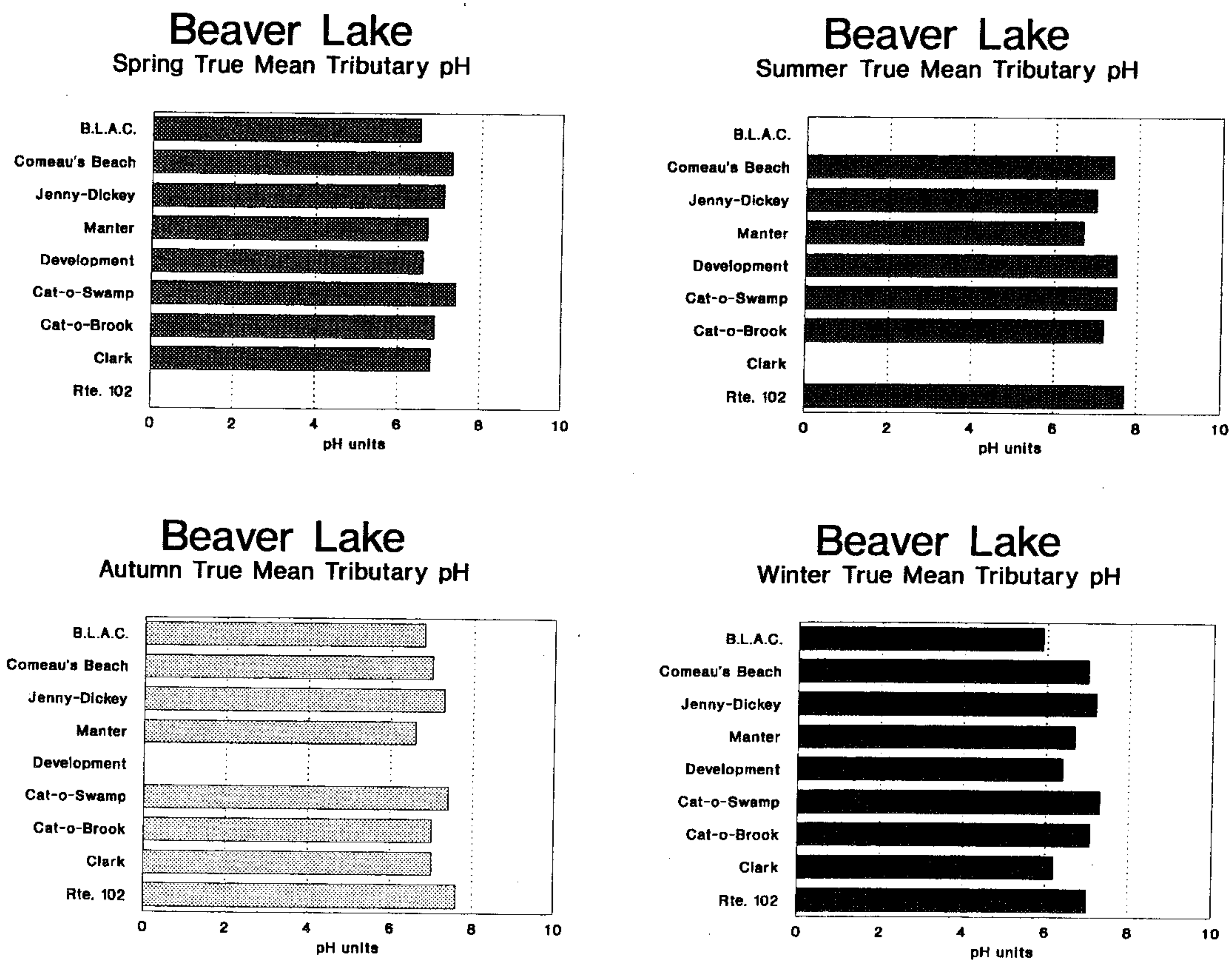


Figure V-2. Seasonal Distribution of Tributary pH

Table V-2
Mean Study Period and Seasonal ANC (mg/L)
for Beaver Lake Tributaries

Station	Study Period (mean/median)	Winter	Spring	Summer	Fall
Outlet 1	19.0	15.7	--	--	22.2
Outlet 2	15.8	--	14.7	17.0	--
B.L.A.C.	3.8/5.4	0.6	5.4	--	5.5
Comeau's Beach Brook	22.5/22.9	21.0	17.1	27.0	24.8
Jenny-Dickey Brook	20.8/18.4	19.4	16.5	30.0	17.3
Manter Brook	13.6/12.4	11.6	11.1	18.4	13.3
Development Brook	27.3/21.6	21.6	14.2	46.2	--
Cat-O-Swamp	50.2/50.2	43.5	36.7	63.4	57.0
Cat-O-Brook	25.8/26.0	26.0	22.6	--	28.9
Clark Brook	26.5/28.1	28.1	21.4	--	30.1
Rte. 102	40.7/35.1	35.1	--	52.8	34.2

Beaver Lake

Tributary ANC Range

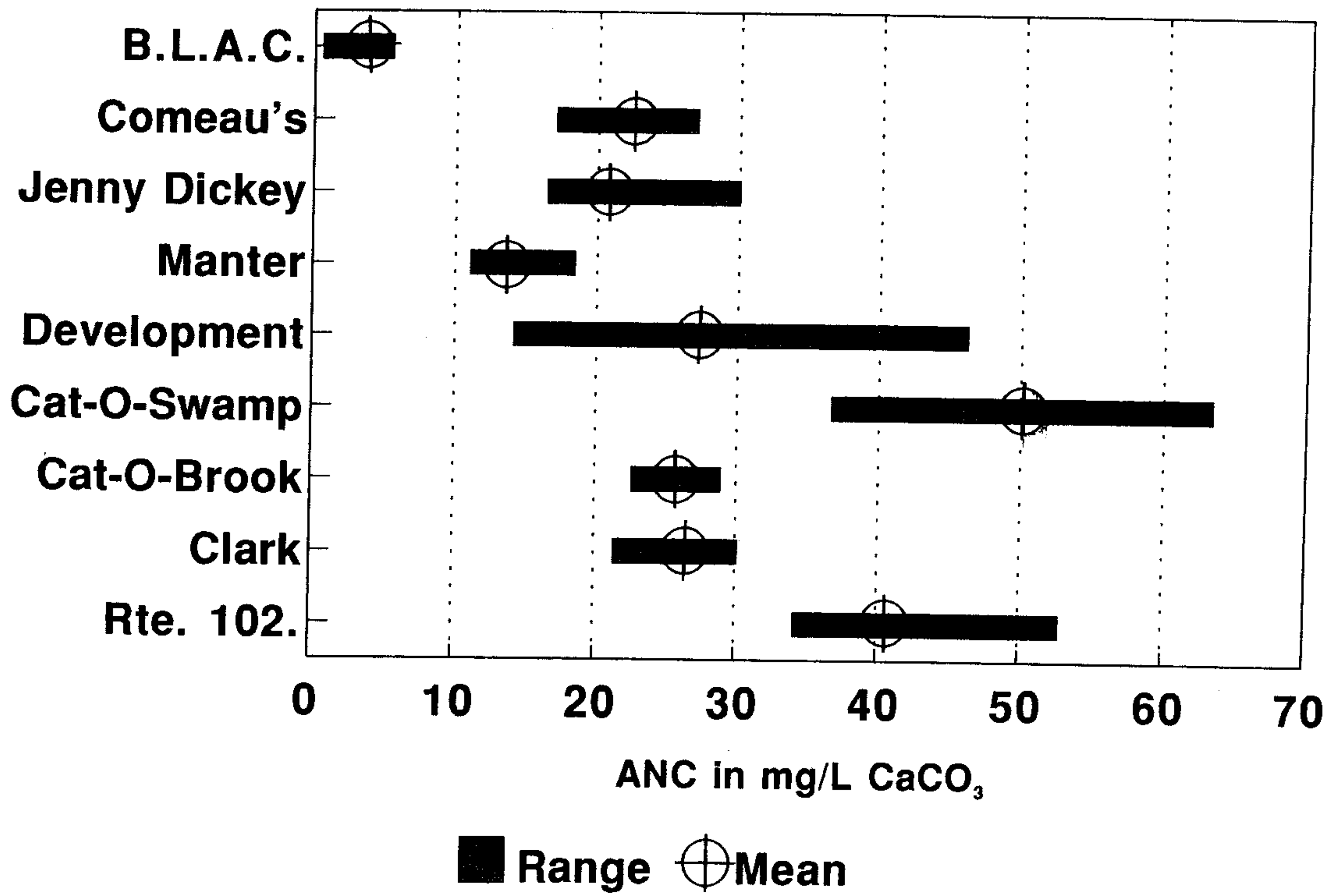


Figure V-3 Tributary ANC R

Table V-3

Lake Data for Study Year
Stratified Season May - Oct 1990 Mean/Median

	Epilimnion	Thermocline	Hypolimnion
pH (units)	7.44	6.96	6.71
ANC (mg/L $CaCO_3$)	17.96/17.10	16.58/16.25	20.27/18.7
Conductivity (umhos/cm)	152.38/158.35	151.21/151.12	159.13/156.20
TP (ug/L)	10.0/10.0	25.6/18.0	21.8/18.0
TKN (ug/L)	317/305	315/305	470/455
Nitrates (ug/L)	57/50	50/50	77/50
Color (units)	26/26	31/28	65/57
Cl (mg/L)	22/27	27/27	27/27
SO_4 (mg/L)	6.5/7	6.5/6.5	4.3/4.1

Table V-3

Lake Data for Study Year
Stratified Season May - Oct 1990 Mean/Median (cont'd)

Unstratified Season	Feb, Mar, Apr, Nov, 1990	Jan 1991
pH (units)	6.93	6.89
ANC (mg/L $CaCO_3$)	14.35/14.35	14.15/14.15
Conductivity (umhos/cm)	154.38/148.10	167.24/148.90
TP (ug/L)	16.8/17.0	14.4/15.0
TKN (ug/L)	360/360	390/390
Nitrates (ug/L)	390/390	420/420
Color (units)	25/24	26/24
Cl (mg/L)	26/26	25.5/25.5
SO_4 (mg/L)	10/10	10/10

D. Specific Conductance

Specific conductance is a measure of the capacity of water to conduct an electrical current. This ability to conduct electricity is determined primarily by the concentration of charged ionic particles present in the waters. The soft waters of New Hampshire generally have a low conductance relative to highly mineralized waters found in some parts of the country. The conductance of water is related to the presence of dissolved solids, and thus is usually higher in sewage than in natural waters. Specific conductance was measured to the nearest umhos/cm using a YSI Model 32 Conductivity meter. The mean conductivity value for all New Hampshire lakes is 56.4 umhos/cm, with a median of 38.0 umhos/cm. Raw chemistry data is presented in Appendix V-3.

a. Tributary and Lake Data

The median tributary values ranged from a low of 66.3 umhos/cm at the B.L.A.C. tributary to a high of 520.0 umhos/cm at Cat-O-Swamp tributary. Mean and median conductivity values for the study period appear in Table V-4. At most of the sampling stations the average standard deviation was below 50, with the exceptions of Development Brook, Cat-O-Swamp and Cat-O-Brook. These stations all had average standard deviations in excess of 50. In Development Brook this was probably due to turbidity which was also highly variable during our study due to construction activities. Cat-O-Brook drains an agricultural area and passes through an automotive repair yard and may be influenced by these factors.

Lake conductivity data can be seen in Table V-3. The conductivity was greatest for both the stratified and unstratified seasons in the lower layer of the lake. This may be due to the sediment release of ionic particles into the overlying waters, and is not an unusual occurrence.

E. Chlorides

Chloride is one of the major anions measured in water. Natural sources of chloride include the weathering of igneous and sedimentary rocks and rainfall (occurring as cyclic chlorides), while artificial sources include many man generated point and nonpoint sources such as road salt runoff and faulty

Table V-4
Mean Study Period and Seasonal Conductivity (umhos/cm)
for Beaver Lake Tributaries

Station	Study Period (mean/median)	Winter	Spring	Summer	Fall
Outlet 1	150.7(161.2)	149.8	147.3	153.1	151.7
Outlet 2	152.0(148.7)	153.0	152.2	153.0	149.2
B.L.A.C.	73.3(66.3)	83.0	74.3	53.4	67.0
Comeau's Beach Brook	237.9(241.6)	223.1	240.1	260.5	234.4
Jenny-Dickey Brook	268.0(259.9)	250.5	250.2	313.3	257.9
Manter Brook	118.5(115.1)	116.1	118.6	124.3	113.3
Development Brook	226.3(99.9)	139.9	91.5	143.8	135.9
Cat-O-Swamp	501.1(520.0)	527.1	418.0	508.4	548.4
Cat-O-Brook	257.0(197.2)	206.6	308.4	292.8	183.7
Clark Brook	272.1(286.0)	213.1	315.5	216.3	314.0
Rte 102	343.7(343.0)	350.0	---	380.0	327.2

septic systems. High concentrations of chlorides often indicate cultural pollution. The median chloride level for New Hampshire lakes is 6 mg/L. Raw chemistry median data is presented in Appendix V-3.

a. Median Tributary Data

Chloride values for the study period ranged from a minimum of 7.0 mg/L at the B.L.A.C. tributary to a maximum of 122.0 mg/L at the Cat-O-Swamp tributary. The mean standard deviation for the majority of the stations ranged under 10 mg/L. Several tributaries, including Cat-O-Swamp, Cat-O-Brook and Clark Brook were exceptions. Clark Brook is located adjacent to Rte. 102 and drains a residential area as it infiltrates through several lawns. There may be an impact here from both road runoff and possible failed septic systems (it also has the highest fecal coliform count). The Cat-O-Brook and Cat-O-Swamp tributaries may also be impacted from Rte 102 as their sampling stations lie adjacent to the road, and drain under it. The seasonal mean chloride value for Cat-O-Brook was highest during the winter months as one would expect from road runoff. However, Cat-O-Swamp's highest value occurred during the summer period. This may be an indication of cultural pollution. Chloride values are depicted in Table V-5.

b. Lake Data

In-lake chloride values are depicted in Table V-3. Median chloride values were 27 mg/L in all layers during the stratified season, and slightly less in the unstratified. These numbers may indicate cultural pollution from leachfield drainage, fertilizer runofff, and runoff from salted roads.

F. <u>Sulfates</u>

Sulfates are utilized by all living organisms for protein synthesis. Sulfates are usually abundant in systems, entering through erosion of rocks, fertilizer runoff and through atmospheric transport by precipitation and dry fall. The mean sulfate concentration for New Hampshire lakes is 4 mg/L.

Table V-6 presents mean tributary sulfate results for the study period. These range from a low of 8.4 mg/L found at Manter Brook to a high of 18.0 mg/L obtained in Cat-O-Swamp. The lake stations (Table V-3) show a minimum seasonal median value of 4.1 mg/L and a maximum of 10.0 mg/L, which compares favorably with other New Hampshire lakes.

Table V-5
Mean Study Period and Seasonal Cl (mg/L)
for Beaver Lake Tributaries

Station	Study Period (mean/median)	Winter	Spring	Summer	Fall
Outlet 1	27.1(27.5)	26.3	28.3	27.3	26.7
Outlet 2	27.4(27.5)	27.7	28.0	27.5	26.0
B.L.A.C.	9.6(7.0)	12.3	10.0	6.0	6.5
Comeau's Beach Brook	45.9(47.5)	42.0	47.0	53.0	43.0
Jenny-Dickey Brook	54.4(53.5)	51.0	53.3	26.3	46.0
Manter Brook	18.4(18.5)	17.7	20.0	18.7	17.3
Development Brook	12.9(8.5)	21.0	9.3	--	5.0
Cat-O-Swamp	112.0(122.0)	87.0	118.3	127.3	115.3
Cat-O-Brook	41.7(35.0)	63.0	34.3	37.0	32.3
Clark Brook	44.8(41.0)	30.0	67.0	35.0	51.0
Rte. 102	49.0(46.0)	52.0	--	57.0	44.3

Table V-6
Mean Study Period and Seasonal SO_4 (mg/L)
for Beaver Lake Tributaries

Station	Study Period (mean)	Winter	Spring	Summer	Fall
Outlet 1	9.1	9.1	--	--	--
Outlet 2	9.4	9.4	--	--	--
B.L.A.C.	9.0	9.0	--	--	--
Comeau's Beach Brook	11.7	11.7	--	--	--
Jenny-Dickey Brook	11.2	11.2	--	--	--
Manter Brook	8.4	8.4	--	--	--
Development Brook	10.0	10.0	--	--	--
Cat-O-Swamp	18.0	18.0	--	--	--
Cat-O-Brook	12.7	12.7	--	--	--
Clark Brook	--	--	--	--	--
Rte. 102	--	--	--	--	--

G. Apparent Color

Apparent color is the visual determination of the darkness of the water. Color in water may result from substances in solution (iron, manganese and leachate from decaying organic matter) and suspended matter (plankton and silt). Tea colored waters (color values greater than 40 cpu's) are generally naturally colored from decaying organic matter. For this reason drainage from wetlands tend to have high color values. Iron and Manganese can also add color to waters. The median color value for New Hampshire lakes is 25 units. Raw color data is presented in Appendix V-3.

a. Tributary Data

Median color values for the tributaries (Table V-7) ranged from a low of 7 CPU's measured in the B.L.A.C. tributary to a high of 94 CPU's measured in Development Brook.

Seasonal highs for color occurred for most of the tributaries in the fall when much decomposition was occurring in the watershed. The Cat-O-Swamp and Cat-O-Brook tributaries had their highest color readings in the summer season, probably due to decomposition in their wetland areas upstream. The highest color values occured in Development Brook during the spring. This is probably due to an increase of construction at that time and discharge from the small retention pond upstream from the sampling station.

b. Lake Data

Table V-3 presents the in lake apparent color for Beaver Lake. Values ranged from a minimum of 16 CPU's to a maximum of 110 CPU's. Median color values for the stratified season reflect higher values in the bottom layer than the top. During the unstratified season the color values were comparable with depth.

H. Turbidity

Turbidity is caused by the presence of suspended or collodial particles of clay, silt, organic matter, and algal cells. As light passes through the

Table V-7
Mean Study Period and Seasonal Color (CPU's)
for Beaver Lake Tributaries

Station	Study Period mean (median)	Winter	Spring	Summer	Fall
Outlet 1	25(23)	32	22	22	37
Outlet 2	24(24)	30	22	23	--
B.L.A.C.	11(7)	6	6	8	27
Comeau's Beach Brook	20(14)	15	20	10	44
Jenny-Dickey Brook	42(33)	26	31	18	96
Manter Brook	58(44)	31	24	74	106
Development Brook	90(94)	85	102	14	--
Cat-O-Swamp	28(18)	7	9	40	32
Cat-O-Brook	51(39)	10	18	82	70
Clark Brook	17(15)	7	13	17	32
Rte. 102	33(24)	7	--	24	69

water, it is scattered, reflected or absorbed by particulate matter in suspension. The amount of light reflected at a 90° angle is directly proportional to the amount of particulate matter suspended in the water. This reflected light is measured by a turbidimeter. Turbidity is reported in Nephelometric Turbidity Units (NTU). Erosion creates high turbidity values, and turbidities are often highest during storm events. High tributary turbidities result in lake siltation and the introduction of phosphorus to the lake or pond. The median turbidity value for NH lakes and ponds is 1 NTU. The mean, seasonal turbidity results for the study period appear in Table V-8, and the raw data in Appendix V-3.

The highest mean and median turbidity were from Development Brook and the lowest mean and median results were measured at Comeau's Beach Brook. In all, samples ranged from a high of 92 NTU's to a minimum of 0.17 NTU's.

In general, the seasonal distribution of tributary data showed the highest turbidities occurred during the fall. There were several exceptions, notably the Cat-O-Tributaries, which had elevated turbidity in the summer; Clark Brook, which is elevated in the spring; and B.L.A.C., which was highest during the winter months. Turbidity was elevated when construction practices occurred near the streams and may be due to this. Turbidity was not analyzed in lake samples.

I. Fecal Coliform

Fecal coliform is a type of bacteria found in the intestinal tract of warm blooded animals, including man. They are used as indicator organisms; high numbers of fecal coliforms suggest that sewage may be present.

A level of 200 fecal coliforms per 100 mL's of water is safe for swimming. Occasionally higher numbers, up to 1,000 in some instances, are not unusual, particularly after storm events and where urban or agricultural runoff occurs. These levels are generally not considered unsafe unless investigation indicates the source to be sewage. Elevated levels can also be caused by ducks, seagulls, beaver or other warm-blooded animals.

Table V-9 presents the mean study period and seasonal fecal coliform data for Beaver Lake tributaries. Raw data can be found in Appendix V-3. The fecal coliform median counts ranged from a low of 4 cts/100mL at B.L.A.C. tributary to a high of 140 cts/100mL at Clark Brook. For the most part the numbers were below 35 cts/100mL.

Table V-8
Mean Study Period and Seasonal Turbidity (NTU's)
for Beaver Lake Tributaries

Station	Study Period (mean/median)	Winter	Spring	Summer	Fall
Outlet 1	0.73(0.58)	0.60	0.58	0.58	1.07
Outlet 2	0.80(0.68)	0.66	0.69	0.68	1.10
B.L.A.C.	1.03(0.55)	2.10	0.78	0.34	0.55
Comeau's Beach Brook	0.60(0.58)	0.75	0.60	0.24	0.80
Jenny-Dickey Brook	2.35(0.86)	0.48	0.68	1.31	5.40
Manter Brook	1.08(0.91)	0.66	0.66	1.35	1.37
Development Brook	18.84(5.35)	9.90	5.10	4.35	56.00
Cat-O-Swamp	1.26(0.56)	0.53	0.44	2.92	0.67
Cat-O-Brook	1.81(1.43)	0.97	0.58	3.15	1.90
Clark Brook	6.93(2.65)	2.60	16.05	2.70	2.10
Rte. 102	0.82(0.80)	0.81	--	0.68	0.87

Table V-9
Mean Study Period and Seasonal FC (counts/100mL)
for Beaver Lake Tributaries

Station	Study Period (mean/median)	Winter	Spring	Summer	Fall
Outlet 1	40(15)	3	6	20	103
Outlet 2	26(10)	18	6	10	106
B.L.A.C.	9(4)	0	0		18
Comeau's Beach Brook	42(20)	0	13	--	106
Jenny-Dickey Brook	62(34)	3	5	167	64
Manter Brook	65(60)	0	30	70	142
Development Brook	129(25)	0	65	30	358
Cat-O-Swamp	39(23)	36	8	25	102
Cat-O-Brook	116(30)	20	103	130	168
Clark Brook	223(140)	--	265	265	140
Rte. 102	92(96)	--	--	80	98

With the exception of Clark Brook, seasonal maximum values occurred in the fall. This may be due to increased runoff during the fall rainy season. Clark Brook had the highest overall values, and had its seasonal maximum values during the spring and summer. This tributary drains through a residential neighborhood before entering the lake.

J. Phosphorus

Phosphorus is an essential element for plant growth, and is the limiting nutrient that regulates the productivity of New Hampshire lakes. Much effort in controlling the eutrophication of lakes has been directed toward controlling the phosphorus load to a lake. Unacceptable levels of phosphorus are usually often associated with human activities, and it appears that, in most cases, the removal or reduction of phosphorus from domestic wastewater will curtail algal productivity in lakes.

Total phosphorus was measured in this study by the persulfate digestion procedure, and includes all phosphorus forms in water. Total phosphorus is composed primarily of organic phosphorus, which includes phosphorus present in algal cells, and inorganic orthophosphate. The total phosphorus range for the summer epilimnetic values for all lakes in NH is between <1 and 121 ug/L, with a median value of 11 ug/L.

The major purpose of this study was to determine significant phosphorus sources to the lake and to propose remediation. Sources of phophorus include: 1) precipitation 2) groundwater 3) surface runoff 4) septic leachate 5) tributary flux and 6) internal phosphorus cycling.

a. Tributary Data

Table V-10 presents the tributary TP data. Raw chemistry data is presented in Appendix V-3. The highest mean total phosphorus concentrations during the study period were observed in Development Brook (132 ug/L) and in Clark Brook (58 ug/L). The lowest mean concentration was recorded in the lakes outlet (13 ug/L). The remainder of the means ranged between 19 ug/L and 26 ug/L. Overall values ranged from a maximum of 1410 ug/L at Development Brook to a minimum of 2 ug/L obtained from the outlet. Median values for the study period were more conservative, ranging from 12-68 ug/L. Figure V-4 depicts the tributary TP range and mean for the study period.

Table V-10
Mean Study Period and Seasonal Total Phosphorus (ug/L) for Beaver Lake Tributaries

Station	Study Period mean (median)	Winter	Spring	Summer	Fall
Outlet 1	13(14)	14	12	11	16
Outlet 2	13(13)	14	12	11	15
B.L.A.C.	31(13)	64	18	12	10
Comeau's Beach Brook	18(14)	21	16	10	22
Jenny-Dickey Brook	23(21)	17	25	23	26
Manter Brook	19(16)	18	13	28	18
Development Brook	132(38)	240	60	40	125
Cat-O-Swamp	19(12)	13	22	13	24
Cat-O-Brook	21(13)	14	12	40	20
Clark Brook	58(68)	22	84	34	62
Rte. 102	26(19)	19	---	54	17

Beaver Lake
Tributary TP Range

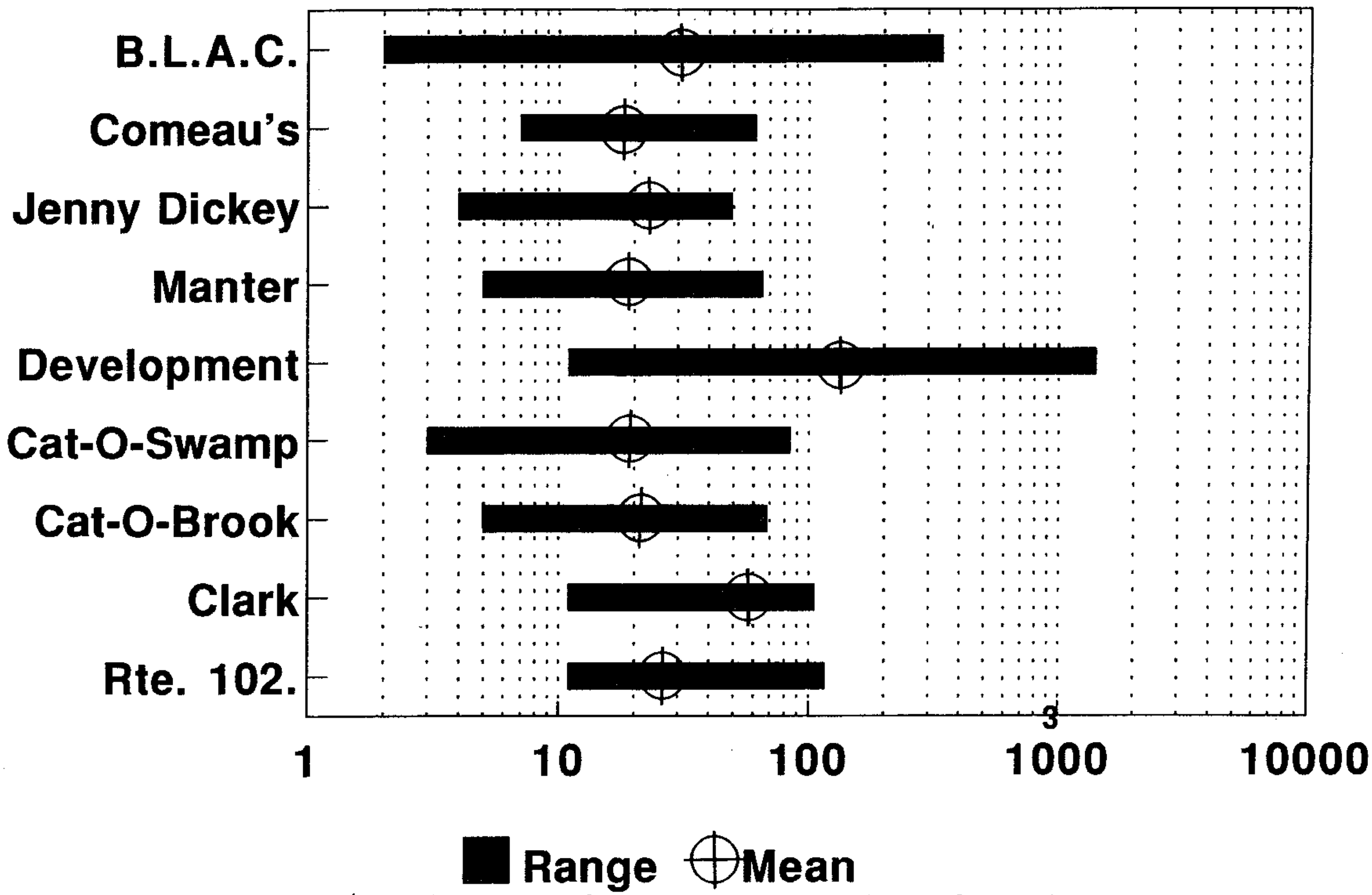


Figure V-4. Tributary Total Phosphorus Range and Mean for Study Year

Three tributaries recorded high mean phosphorus values during the summer months. Two of these, Manter Brook and Cat-O-Brook drain extensive agricultural areas, and as such may be affected by fertilizer runoff. The other tributary, Rte. 102, drains a residential area and may be affected by lawn fertilizer.

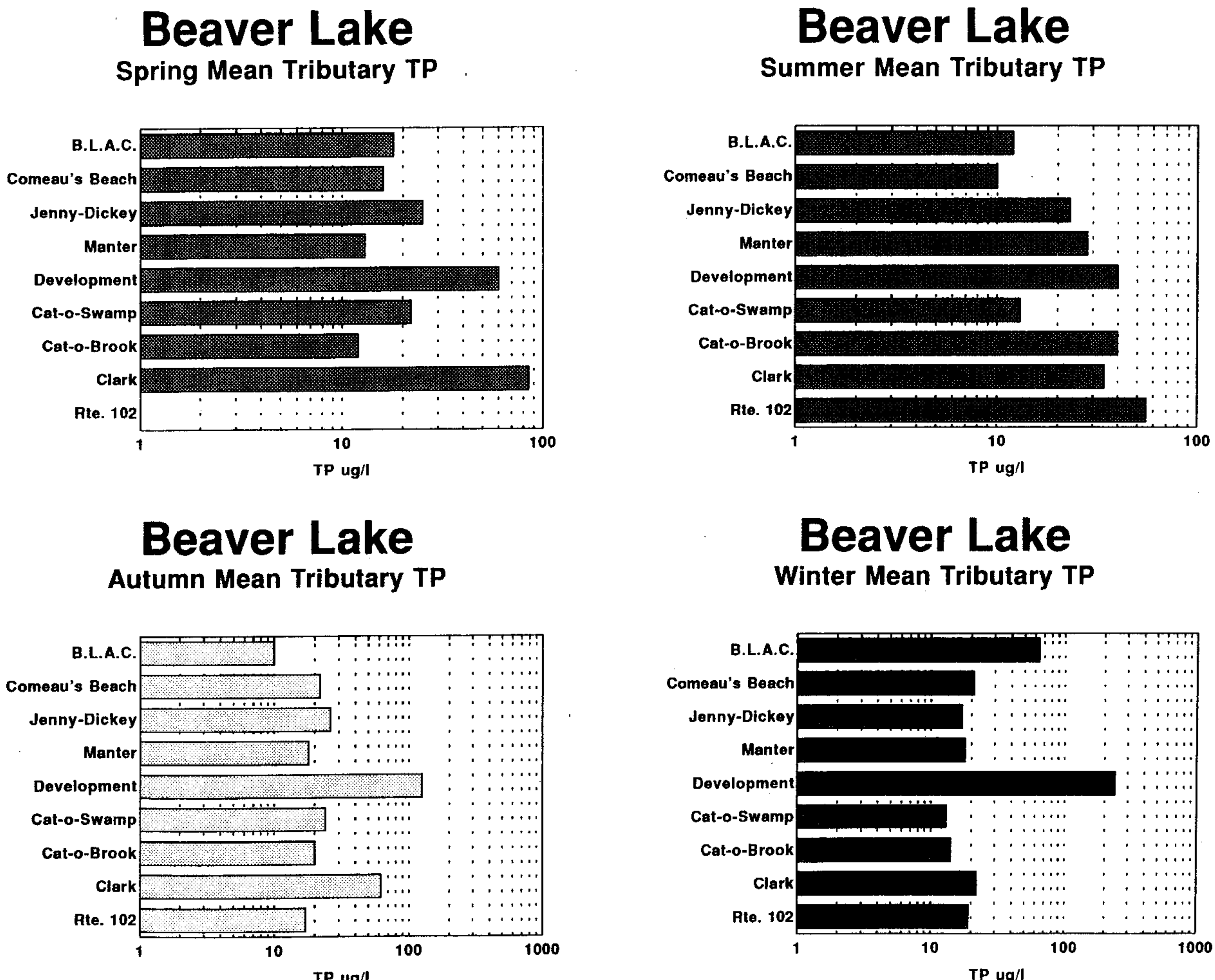
The greatest mean phosphorus value at Clark Brook was measured during the spring. The high concentration may be attributed to runoff from neighborhood yards.

The B.L.A.C. tributary and Development Brook recorded their highest mean TP values in the winter months. This may be a result of the construction practices occurring in the surrounding areas at that time, and their subsequent erosion. The remainder of the tributaries showed no marked seasonal variation in TP concentration. Seasonal tributary TP mean values are shown in Figure V-5.

It should be noted that tributaries with a high mean phosphorus concentration are not necessarily the most significant contributors of phosphorus to the lake system. The amount of discharge in total volume plays a more important part in phosphorus loading. The tributary with the highest mean phosphorus, Clark Brook, contributed the least in volume of all the tributaries, and contributed the least phosphorus loading to the lake. This is in contrast to Manter Brook, which had a mean phosphorus value of only 19 ug/L but contributed the majority of phosphorus entering the lake from the tributaries.

b. Lake Data

During the stratified season the total phosphorus concentrations ranged from 6-13 ug/L (mean of 10 ug/L) in the epilimnion, from 12-90 ug/L (mean of 25.6 ug/L) in the thermocline and from 12-37 ug/L (mean of 21.8 ug/L) in the hypolimnion. Reference Table V-3 for mean data and appendix V-3 for raw data. Table V-11 shows seasonal phosphorus values for the lake for both the study year and the extended study period. Both years showed similar patterns. During June the total phosphorus maximum occurred in the thermocline. The July results revealed a shift in phosphorus maximum to the bottom layer of the lake, but August, however, showed the maximum phosphorus values again in the thermocline.



Note:Scales Are Different

Figure V-5. Seasonal Tributary TP Mean Values

Table V-11

Study Year and Total Study Mean Total Phosphorus (ug/L)
Lake Values for Summer Months

	(1990) Study Year			(1990 + 1991) Extended Study Period		
	Epilimnion	Thermocline	Hypolimnion	Epilimnion	Thermocline	Hypolimnion
June	11.0	54.5	15.5	8.7	40.0	13.7
July	10.5	17.0	25.5	10.3	17.3	24.0
Aug.	9.0	12.5	9.5	10.0	24.0	22.7
Mean	10.0	25.6	21.8	9.7	27.1	20.1

	Stratified Season (May through October)			Unstratified Season (November through April)	
	Epilimnion	Thermocline	Hypolimnion	Upper	Lower
Mean	10.0	25.6	21.8	16.8	14.4
Median	10.0	18.0	18.0	17.0	15.0

The June thermocline maximum may be due to the population of algae concentrating at that level, attracted by the nutrients recirculated at spring turnover which get trapped by thermal stratification. The July hypolimnion maximum indicates phosphorus release from the sediments under anoxic conditions. The August maximum again occurred in the thermocline. While sediment phosphorus release was still occurring inthe hypolimnion, the algae population dominance had shifted to blue-green species. These algae are able to regulate their buoyancy and migrate throughout the water column. A rise to the thermocline had the advantages of increased sunlight penetration and decreased shading.

During the unstratified season the phosphorus ranged from 14-20 ug/L (mean of 16.8) in the upper layer and ranged from 10-17 ug/L (mean of 14.4 ug/L) in the lower layer. This depicts similar values at different depths as would be expected prior to lake turnover.

K. Nitrogen

A component of proteins, nitrogen is a major nutrient essential for plant growth. Nitrogen may be present in water as dissolved nitrogen gas, organic nitrogen compounds and inorganic nitrogen compounds including ammonia, nitrite and nitrate.

With the exception of some bluegreen algae that utilize atmospheric nitrogen (N_2), most algae use inorganic nitrogen. Of the forms listed ammonia is the preferred source because it is already at the reduction level of organic nitrogen, and thus is assimilated into protein at a minimal energy cost. Ammonia nitrogen is gradually oxidized by nitrifing bacteria into nitrite and nitrate.

Sources of nitrogen include precipitation, nitrogen fixation in the water and sediments by bacteria and certain bluegreen algae, and inputs from surface and groundwater drainage. Natural sources of the most commonly used form, ammonia, include excretory products from ammonifying bacteria, zooplankton and the urea of higher animals such as found in raw sewage (Martin and Goff, 1972; Keeney, 1972; Brezonik et al. 1973).

Total Kjeldahl nitrogen (TKN) (which includes organic nitrogen and inorganic ammonia nitrogen) and inorganic nitrate nitrogen were the forms determined at Beaver Lake. Median values of both forms for summer epilimnetic samples of New Hampshire lakes and ponds are 0.35 mg/L and 0.05 mg/L respectively. Mean seasonal TKN and nitrate values for Beaver Lake tributaries are depicted in Tables V-12 and V-13.

1. TKN Tributary Data

Median TKN values were greatest at Jenney-Dickey Brook (0.52 mg/L) and least at the B.L.A.C. tributary (0.11 mg/L). Total values ranged from a minimum of 0.10 mg/L (B.L.C.A. tributary) to a maximum of 2.0 mg/L (Rte. 102 tributary).

The majority of the tributaries had TKN maxima in the winter. Several tributaries showed summer maxima; these were Cat-O-Brook, Manter Brook and Jenny-Dickey Brook. The former two drain agricultural land and the increase may be due to fertilizer runoff which is high in nitrogen. Comeau's Beach Brook showed a spring maxima and Development Brook a fall maxima.

2. TKN Lake Data

TKN data for the stratified and unstratified seasons appears in Table V-3. Values for the stratified season were similar in the upper two layers of the water column, and increased in the hypolimnion. This may be due to several factors, including decomposition occurring at the sediment interface and the release of nitrogen into the overlying water column and leachfield drainage. The unstratified season showed similar values at both depths. The values from Beaver Lake are similar to values observed in other surveyed lakes around the state.

3. Nitrate Tributary Data

Mean study period and seasonal data are presented in Table V-13. Cat-O-Swamp exhibited the highest mean nitrate composition (1.15 mg/L), while Development Brook showed the lowest (0.06 mg/L). It was observed that nitrate concentrations are commonly high during the winter months (Dec-April) and achieve their minimum concentration during the summer when biological productivity (and therefore increased nutrient demand) is at its maximum peak (Feth, 1966 and Domogalla et al 1926). This is difficult to correlate to the Beaver Lake data due to a lack of a summer data, but most tributaries showed

Table V-12
Mean Study Period and Seasonal TKN (mg/L)
for Beaver Lake Tributaries

Station	Study Period mean (median)	Winter	Spring	Summer	Fall
Outlet 1	0.31(0.39)	0.25	0.33	0.39	0.27
Outlet 2	0.29(0.34)	0.40	0.14	0.34	--
B.L.A.C.	0.30(0.11)	0.70	0.11	--	0.10
Comeau's Beach Brook	0.32(0.26)	0.23	0.54	0.22	0.29
Jenny-Dickey Brook	0.51(0.52)	0.60	0.33	0.65	0.45
Manter Brook	0.28(0.26)	0.17	0.16	0.42	0.35
Development Brook	0.54(0.46)	0.40	0.44	0.48	0.85
Cat-O-Swamp	0.36(0.36)	0.43	0.30	0.37	0.34
Cat-O-Brook	0.34(0.35)	0.32	0.11	0.54	0.38
Clark Brook	0.48(0.41)	0.68	0.41	--	0.36
Rte. 102	0.88(0.38)	0.38	--	2.00	0.27

Table V-13
Mean Study Period and Seasonal Nitrates (mg/L)
for Beaver Lake Tributaries

Station	Study Period mean (median)	Winter	Spring	Summer	Fall
Outlet 1	0.32(0.47)	0.43	0.36	--	0.05
Outlet 2	0.40(0.36)	0.43	0.36	--	--
B.L.A.C.	0.23(0.24)	0.28	0.23	--	0.11
Comeau's Beach Brook	0.83(0.93)	1.02	0.89	--	0.39
Jenny-Dickey Brook	0.43(0.48)	0.66	0.34	--	0.05
Manter Brook	0.32(0.36)	0.50	0.21	--	0.06
Development Brook	0.06(0.05)	0.06	0.05	--	0.05
Cat-O-Swamp	1.15(1.18)	1.33	1.50	--	0.44
Cat-O-Brook	0.74(0.52)	1.29	0.34	--	0.06
Clark Brook	1.02(1.12)	1.12	0.45	--	1.50
Rte. 102	0.84(0.84)	1.51	--	--	0.17

seasonal maximums in the winter months. The exceptions were Manter Brook and Cat-O-Swamp Brook which had seasonal maximums in the spring, and Clark Brook's which showed its greatest concentration during the fall months. Manter Brook's maximum spring value may be due to agricultural runoff.

4. Nitrate Lake Data

The lake data for nitrates follows the same trend as TKN. The stratified season showed a maximum mean value in the hypolimnion with similar epilimnion and thermocline values. The unstratified season had similar values at both sample depths. While studying the nitrogen cycle Keeney (1972) observed that in temperate lakes subject to density stratification, nitrate levels in surface water revealed maximum values in the spring, and minimum values in late summer. The late summer minimum concentrations are believed to be caused by both utilization by organisms and anoxic lake conditions causing denitrification of these intermediate forms of nitrogen. The Beaver Lake data depicts this well. Median values for all depths during the stratified season were 0.05 mg/L while the unstratified season showed much greater values of 0.39 to 0.42 mg/L.

L. Limiting Nutrient

In addition to carbon dioxide, water, and sunlight, all green plants require certain inorganic substances in order to manufacture food through the process of photosynthesis. These inorganic substances are often referred to as plant nutrients.

Phosphorus and nitrogen are the two most important plant nutrients in lake systems for determining the amount of plant growth. Given suitable physical factors, such as temperature and sunlight, the phytoplankton in a lake will continue to reproduce until one of the nutrient sources is depleted. This substance is termed the limiting nutrient. Based on the relative abundance of the nutrients required by the phytoplankton and the levels commonly found in lakes, phosphorus or nitrogen is nearly always the limiting nutrient. Which of these two is limiting in a given lake can be determined by comparing the concentration of nitrogen and phosphorus in the water. Sakamoto (1966) stated that if the TN:TP ratio was greater than 15 to 17, the lake was phosphorus limited; if they were less than 9 to 10, it was nitrogen limited; and if they were between 10 to 15, a balanced condition existed. The limiting nutrient calculation is most meaningful when applied to surface waters during the summer growing season.

Table V-14 presents the TN:TP ratio's for Beaver Lake. TN:TP ratio's in June and August exceed 16, and the July ratio was between 10 and 15. Therefore, for a majority of the growing season the lake is clearly phosphorus limited. Any reduction in phosphorus sources to Beaver Lake should reduce algal growth and improve lake quality.

Table V-14
Limiting Nutrient to Beaver Lake by Comparison of TN:TP ratio's for entire study period

Month	Mean Nitrogen TKN-mg/L	Mean Phosphorus TP-mg/L	Ratio TN:TP
June	0.35	0.021	16.7
July	0.23	0.017	13.5
Aug	0.32	0.019	16.8

M. Storm Event Monitoring

As part of the monitoring program, water quality was sampled during a significant rain event. This occurred on 8/19/91 when the Northeast was struck by Hurricane Bob. The Biology Bureau had the unique opportunity of sampling the pond and its tributaries during the most significant rainfall event of the study period. A record 6.18 inches of rain fell during the storms duration, as recorded at the Manchester Water Works, approximately 7 miles from the lake.

During the rain event the following parameters were measured: stream flow, total phosphorus, turbidity and bacteria. These parameters were chosen because they can significantly increase during storm events due to runoff washing material into streams. Turbidity and bacteria are discussed below. Stream flow is discussed in Chapter VII and phosphorus loading from storm events is discussed in Chapter VIII. The results are presented in Table V-15 and Figure V-6. Raw data is presented in Appendix V-4.

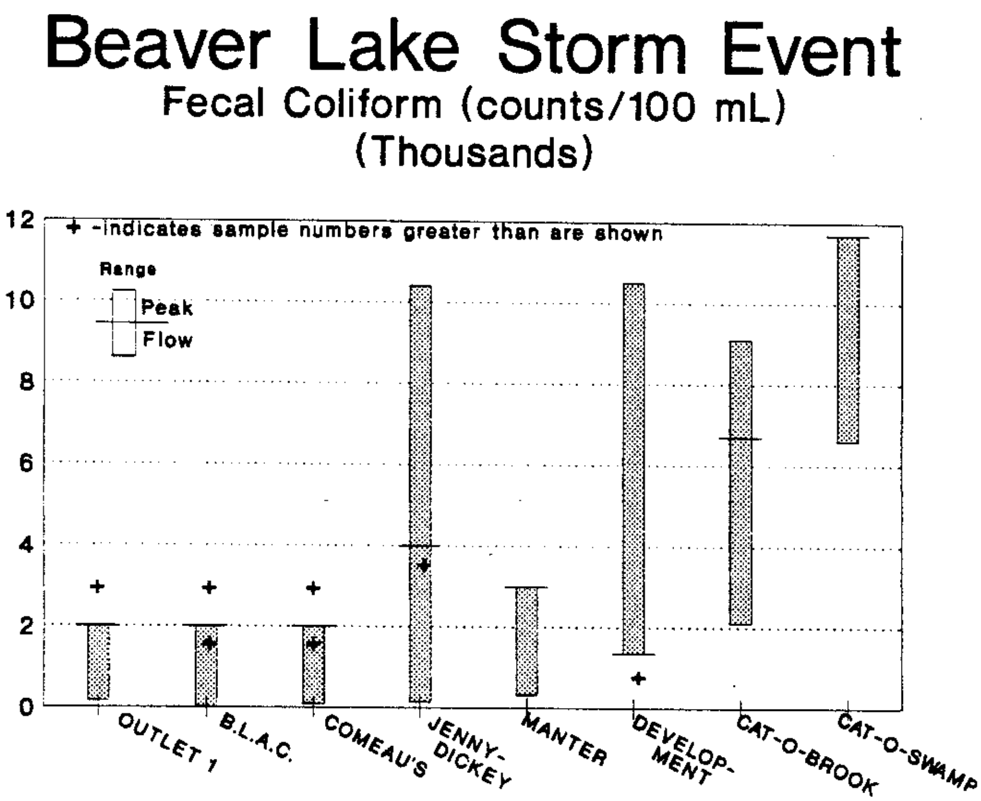
The initial samples were collected approximately one hour after the steady rain began. These samples probably reflected elevated levels due to runoff.

Table V-15
Storm Event Turbidity, TP and FC Values

Station	Turbidity (NTU) typical	Turbidity (NTU) initial	Turbidity (NTU) peak	TP (ug/L) typical	TP (ug/L) initial	TP (ug/L) peak	FC (counts/100mL) typical	FC (counts/100mL) initial	FC (counts/100mL) peak
		range			range			range	
Outlet 1	.560	.7	19	.012	.010	.099	20	170	>2000
		.7 ----- 19			.01 ------ 0.99			170 ------ >2000	
Outlet 2	.680	.9	--	.012	--	--	10	80	--
B.L.A.C.	.340	46	416	.012	.213	.545	19	>2000	>2000
		46 --- 664			.162 ---- .695			>2000	
Comeau's	.235	12.2	50	.010	.196	.265	106	>2000	>2000
		12.2 -- 50			.105 ---- .265			>2000	
Jenny Dickey	1.31	22	18	.024	.097	.220	150	>2000	4000
		18 --- 68			.097 ---- .292			>2000 ---- 10,400	

Table V-15
Storm Event Turbidity, TP and FC Values (contd.)

Station	Turbidity (NTU) typical	Turbidity initial	Turbidity peak	TP (ug/L) typical	TP initial	TP peak	FC (counts/100mL) typical	FC initial	FC peak
Manter	.950	1.20	3.7	.026	.028	.072	60	330	3000
range		1.7 -- 8.7			.028 ---- .135			330 ---- 3000	
Development	4.35	24	125	.034	.096	.290	30	>2000	10500
range		12 --- 125			.96 ----- .378			>2000 ----10500	
Cat-O-Brook	2.8	13.2	44	.042	.123	.195	30	2100	6700
range		13.2 --- 44			.121 ---- .195			2100 --- 9100	
Cat-O-Swamp	1.44	8.1	5.5	.010	.081	.052	25	6600	11700
range		3.7 --- 15			.081 ---- .146			6600 ----- 11700	



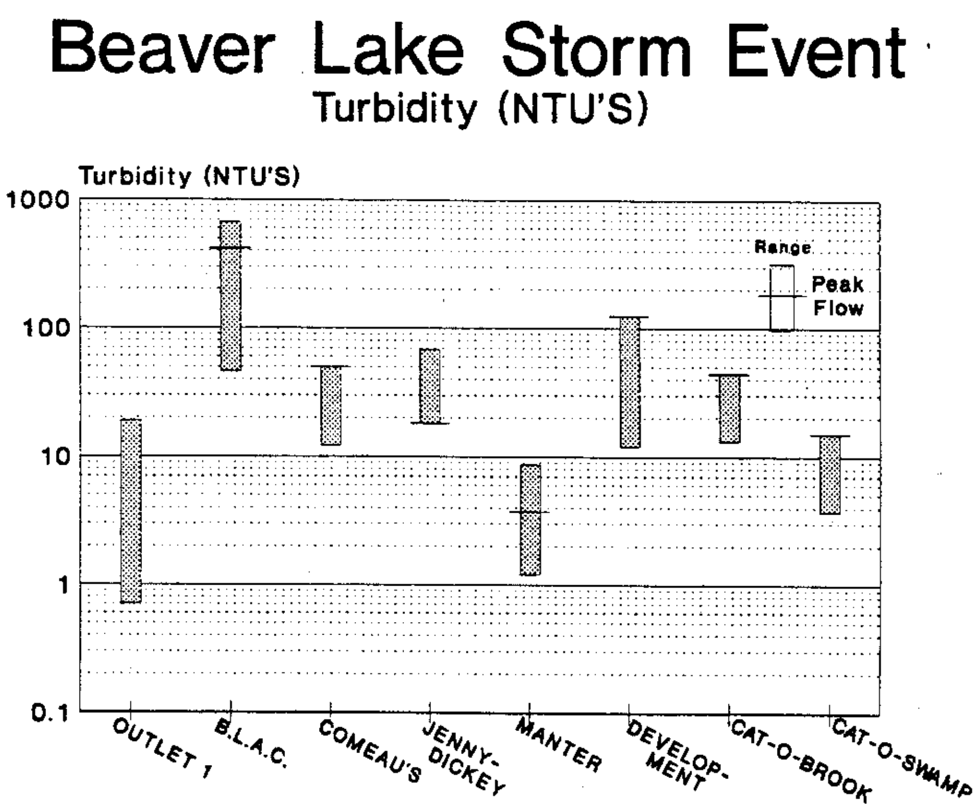


Figure V-6. Beaver Lake Storm Event Fecal Coliform and Turbidity Results

Therefore, typical (mean) seasonal values of analyses are included in the table to present a fair background for comparison.

Initially, the locations with the lowest fecal coliform values were the outlets of the lake (170 and 80 counts) respectively and Manter Brook. This is not surprising. Lakes are large settling basins and much of the storm event phosphorus, turbidity and bacteria discharge became incorporated into the lake system before being flushed out through the outlets. Also, this was the beginning of the storm and the outlets discharged lake water which had not received much runoff at that early phase. Manter Brook had the largest watershed of the brooks allowing for a longer water residence time and resulting in lower initial counts. All of the other tributaries showed in excess of 2000 counts/100mL with a maximum count of 6600 occurring at Cat-O-Swamp Brook. Figure V-6 displays fecal coliorm values for the storm event. The tributaries which had greater than 2000 counts/mL are indicated by + marks. Again, background "typical" values are used for minimum data points. Refer to Table V-15 to aid in comprehension.

At the height of the storm, estimated to be somewhere around 4:00 E.S.T., the FC counts had risen dramatically. The lowest figures again included the outlets, which registered in excess of 2000 counts/mL. The highest figures were recorded at Cat-O-Swamp Brook and Development Brook,which registered 11,700 and 10,500 counts/100ml respectively. These figures may be due to the watershed areas of the tributaries. Cat-O-Swamp, as its name implies, drains from a swamp, which are well known nutrient sinks. Heavy rainfall allows the swamp to purge itself of decaying material and its accompaning nutrients and bacteria. Development Brook drains a recently developed area which did not have much ground cover over the newly exposed land at the time of the hurricane, and was easily eroded. It also drained out of a small retention pond which had collected sediment and other materials over the course of the study.

All other tributaries at the height of the storm contained in excess of 2000 counts/100mL. At the end of the sampling period none of the fecal coliform counts had decreased to near the numbers of the initial sampling.

Initial turbidity samples during the rain event ranged from a minimum of .7 NTU's, obtained from the outlet, to 46 NTU's, collected from the B.L.A.C. tributary. Maximum flow levels ranged from a minimum of 3.7 from Manter Brook to a maximum of 664 NTU's obtained again from the B.L.A.C. tributary.

Turbidity increased to varying degrees at all stations. The majority of the samples remained below 50 NTU's for the duration of the storm event, with the exception of the B.L.A.C. tributary. The excessive turbidity of the stream, that stayed in the triple digits for most of the rain event, may be due in part to its watershed. It drains an area that is almost 100% developed and, as such, has little open land. This contributes to a short water retention time, and therefore a greater erosion potential. The copius amounts of water discharged during the event caused the tributary to flood its narrow banks and wash out the road adjacent to the staff gage and sampling site.

The tributary from Development Brook also had values at the high end of the scale, probably due to the aforementioned unstabilized earth.

VI. AQUATIC ECOLOGY

A. Chlorophyll-a and Plankton

Chlorophyll-a is the green pigment found in plants which allows them to convert sunlight to energy.

right The mean and median chlorophyll-a concentrations for lakes in the state are 7.27 ug/L and 4.54 ug/L respectively. Values for the Beaver Lake study year appear in Table VI-1. Mean monthly chlorophyll-a values ranged from a minimum of 1.82 ug/L in February to a maximum of 20.78 ug/L in November. Most of the samples fell between 2 and 9 ug/L.

Phytoplankton and zooplankton were collected in plankton nets (80 micron mesh net) and were identified to genus. The relative abundance of each genus was computed, both cells/Liter and percent. Net phytoplankton data is given in Table VI-1. Net dominant zooplankton data is given in Table VI-2. Raw biology data is presented in Appendix VI-1. Whole water phytoplankton (which includes species smaller than 80 microns) data is presented in Table VI-3 and Appendix VI-2. Analytical procedures are outlined in Chapter IV-G-2. (NOTE: Colonies, filaments and single cells are all counted as a single standard unit.)

Seasonal succession is the term used to describe the changes in phytoplankton population dominance at different times of the year. In general, these changes are believed to be the result of the organisms response to changing light, temperature and nutrient conditions, and also the result of zooplankton grazing. Different types of phytoplankton are suited to different conditions and become dominant at those times.

During both the winter and spring at Beaver Lake the dominant net phytoplankton type was Diatoms. This has been observed in many other temperate dimictic lakes. Diatoms are well suited to low light, low temperature environments such as occur under ice conditions in the winter and the cool days of spring. Spring turnover recirculates nutrients throughout the water column and also contributes to diatom blooms.

The bloom will generally end when these conditions change: the nutrients are depleted from the water column, the sunlight becomes stronger and the waters become warmer and stratify. Another factor for the end of the bloom may be zooplankton grazing on the Diatoms.

Table VI-1
Chlorophyll-a, Secchi Disk and Dominant Net Phytoplankton for Study Year

Month	Chlorophyll-a Sample	ug/L Mean	Secchi Disk (M)	Mean	Dominant Net Phytoplankton	% abun.
Feb 90	1.82	1.82	---		Asterionella	96
Mar 90	---	---	---		Asterionella	80
Apr 90	2.18	2.18	3.6	3.6	Asterionella	49
May 90	3.82	3.82	3.6	3.6	Asterionella	94
June 90	6.99	6.99	3.4		Tabellaria	64
	--	--	]-	3.7		
			4.0		Tabellaria	57
July 90	10.28		4.2		Dinobryon	36
	]-	7.75	]-	4.5		
	5.21		4.8		Ceratium	46
Aug 90	8.89		3.9		Coelosphaerum	44
	]-	9.07	]-	3.8		
	9.24		3.7		Oscillatoria	48
Sept 90	6.99		4.4		Coelosphaerum	38
	]-	6.42	]-	4.5		
	5.85		4.6		Asterionella	58
Oct 90	6.97	6.97	4.5	4.5	Coelosphaerum	45
Nov 90	20.78	20.78	2.3	2.3	Synura	86
Jan 91	---	---	---	---	Asterionella	76

Plankton Groups

Diatoms (Bacillariophyceae) - Asterionella, Tabellaria

Chrysophytes - Dinobryon, Synura

Dinoflagelates - Ceratium

Blue Green's (Cyanobacteria) - Coelosphaerum, Oscillatoria

Table VI-2

Beaver Lake Dominant Zooplankton

Date	Zooplankton SPP #1	#/ml	%	Zooplankton SPP #2	#/ml	%	Zooplankton SPP #3	#/ml	%
2/13/90	Nauplius	71.0	70	Cyclopoid	21.8	28			
3/13/90	Nauplius	67.6	72	Cyclopoid	10.9	12	Bosmina	4.4	5
4/03/90	Nauplius	50.1	64	Cyclopoid	26.2	33			
5/10/90	Nauplius	125.6	37	Polyarthra	84.6	25	Kertella	43.6	13
6/13/90	Nauplius	20.0	30	Keratella	14.6	22	Kellicottia	12.7	19
6/28/90	Kellicottia	19.6	65	Polyarthra	15.3	51			
7/13/90	Kellicottia	29.0	40	Nauplius	21.8	30	Daphnia	18.2	25
7/27/90	Kellicottia	21.8	27	Keratella	17.4	22	Daphnia	15.3	19
8/10/90	Keratella	17.4	22	Polyarthra	17.4	22	Nauplius	15.3	19
8/24/90	Nauplius	26.2	32	Keratella	21.8	26	Kellicottia	17.4	21
9/7/90	Keratella	26.2	33	Polyarthra	21.8	28	Kellicottia	17.4	22
9/21/90	Nauplius	26.2	23	Keratella	24.0	21	Kellicottia	24.0	21
10/5/90	Kellicottia	327.6	83	Calanoid	18.0	5			
11/12/90	Kellicottia	30.5	44	Keratella	10.9	16			
1/25/90	Nauplius	19.6	35	Kellicottia	15.3	27	Keratella	15.3	27

Table VI
Beaver Lake Whole Water Phytoplankton
Dominant Densities

Date	Phytoplankton SP #1	#/ml	%	Phytoplankton SP #2	#/ml	%	Phytoplankton SP #3	#/ml	%
5/10/90	Chroomonas	669.6	42	Asterionella	194.4	12	Tiny Flagellates	190.1	12
6/13/90	Chroomonas	665.3	50	Cyclotella	237.6	18			
6/28/90	Chroomonas	267.8	31	Tabellaria	116.6	13	Tiny Flagellates	116.6	13
7/13/90	Chroomonas	306.7	29	Cryptomonas	168.5	16			
7/27/90	Chroomonas	276.5	34	Cryptomonas	95.0	12			
8/10/90	Chroomonas	125.3	20	Cryptomonas	90.7	15			
9/7/90	Cryptomonas	125.3	26	Tiny Flaggelates	116.6	24	Chroomonas	112.3	23
9/21/90	Chroomonas	169.9	31	Cryptomonas	121.0	22	Asterionella	66.2	12
10/5/90	Chroomonas	149.0	42	Tiny Flaggelates	116.6	33			
11/12/90	Synura	144.7	38	Mallamonas	77.8	21			

Group Divisions

Cryptomonads - Chroomonas, Cryptomonas
Diatoms - Cyclotella, Tabellaria, Asterionella
Chrysopkytes - Synura, Mallamonas

Chlorophyll values for this time period ranged from 1.82 ug/L to 6.99 ug/L. The mean chlorophyll value for New Hampshire lakes sampled is 6.6 ug/L. wrong

A shift in dominance to the Chrysophyte Class occurred in early June. With this switch was an accompanying increase in chlorophyll-a to 10.28 ug/L. The chlorophyll dropped, however, later in the month as the Dinoflagellate group became predominant.

From August through September the Cyanobacteria were the paramount type of phytoplankton observed. The chlorophyll-a concentration at this time ranged from 6.99 to 9.24 ug/L. This dominance was interrupted in late September when the Diatom population surged.

The chlorophyll-a concentration receeded to 5.85 ug/L during the Diatom dominance but increased again to 6.97 ug/L when the Cyanobacteria regained predominance in the October sampling.

In November the highest chlorophyll-a concentration was recorded (20.78 ug/L) when the most common plankton type became the Chrysophytes. Chrysophytes are also well suited to low light and low temperature conditons and were responding to the high nutrient availability present after the fall turnover.

B. Transparency

The evaluation of the transparency of water to light was conducted using a Secchi disk. The transparency of the water refers to the depth where a weighted black and white disk (20 cm in diameter) disappears from view while being lowered into the water from the shady side of a boat. This is essentially a function of the reflection of light from its surface, and is influenced by the absorption characteristics of both the water and its dissolved organic matter and suspended material (both living and dead). Unless large amounts of silt are present, there is generally an inverse correlation between chlorophyll-a and Secchi disk, so that as the phytoplankton population increases the clarity decreases. Thus Secchi disk readings are often utilized to estimate algal populations or aesthetic quality. Transparency data is portrayed in Table VI-1. Figure VI-1 depicts the chlorophyll-a and transparency correlation for Beaver Lake.

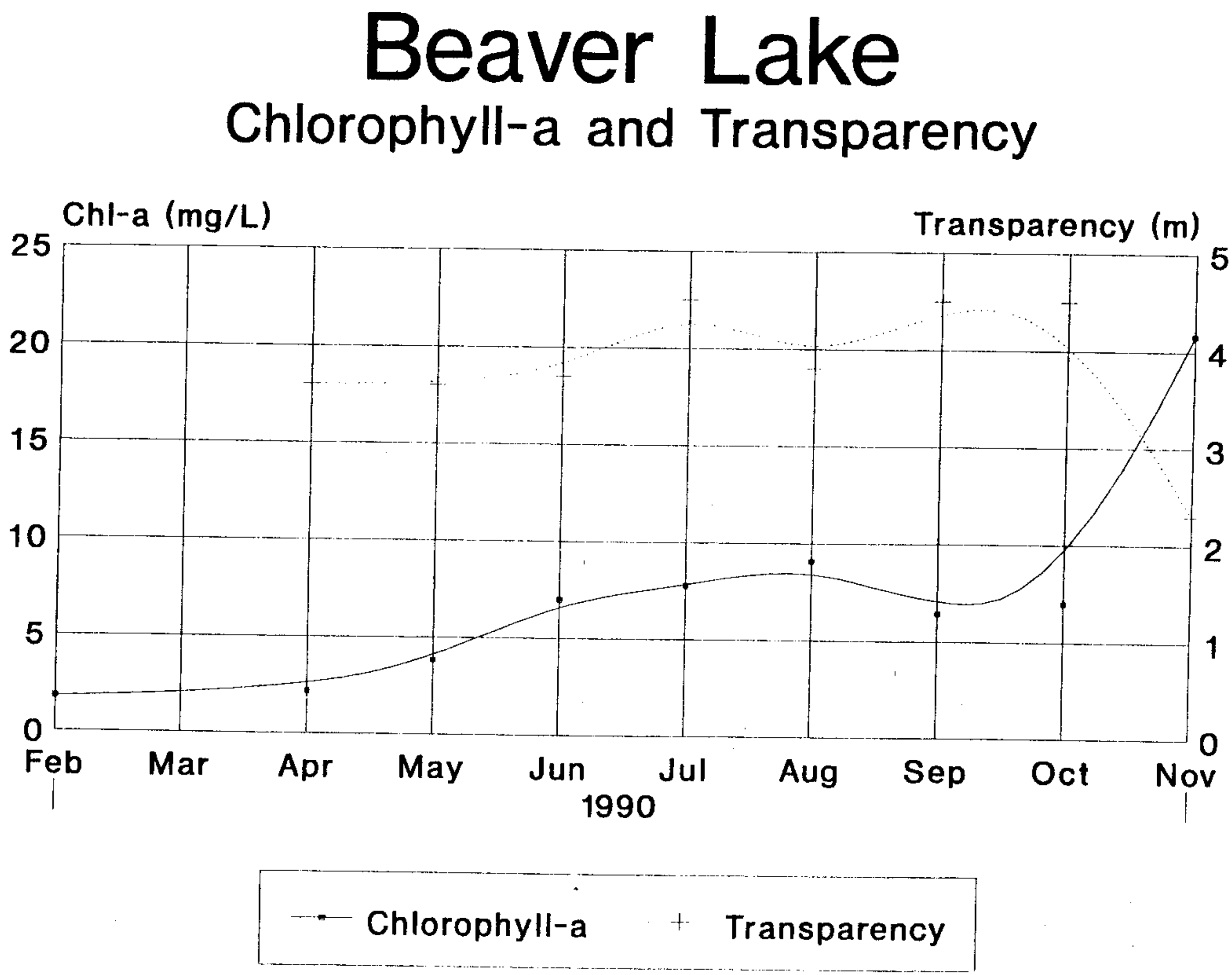


Figure VI-1. Chlorophyll-a and Transparency Correlation

C. Vascular Plants

The Biology Bureau of N.H. Department of Environmental Services, as part of the lake and pond inventory program, constructed an aquatic plant distribution and abundance map for Beaver Lake in 1977 and again in 1984. Figures VI-2 and 3 and Tables VI-4 and 5 present the results of those surveys. The 1977 survey had an overall abundance of very abundant and with Potomogeton robbinsii the most common macrophyte. The next survey was conducted in 1984. At that time, the rating had decreased to abundant and the most common macrophyte had remained the same. The two surveys showed basically the same types and abundances of weeds in the lake.

D. Fisheries

Beaver Lake was first stocked in 1938 by NH Fish and Game. At that time the lake was managed as a two tiered fishery (warm and cold water species). Types of fish stocked included smallmouth bass, horned pout, white and yellow perch, chain pickerell and both rainbow and brook trout.

Fish population studies on the lake were conducted in 1963. At that time the recommendation was to reclaim the pond and re-stock with either trout or warmwater fish. The presence of a serious infestation of bass tapeworm and an abundance of trash fish made further bass management impractical. The lake was subsequently reclaimed in 1972. Since that time it has been stocked yearly with either brook or rainbow trout, despite the lake's bottom dissolved oxygen depletion, and managed primarily as a put and take fishery.

E. Complaints

The Biology Bureau investigated several complaints in and around Beaver Lake. Many of them were either a direct or indirect result of construction practices involved with the sewer installation project around the lake during the study. These complaints included excessive turbidity problems, contaminated wells and suspected failed septic systems.

Other complaints in the area dealt with high bacteria counts, from both animal-suspected and human-suspected sources. There was one complaint involving a suspicious open water area of the lake during the winter months.

BEAVER LAKE

DERRY

DISTRIBUTION OF AQUATIC PLANTS

AUG. 16, 1977

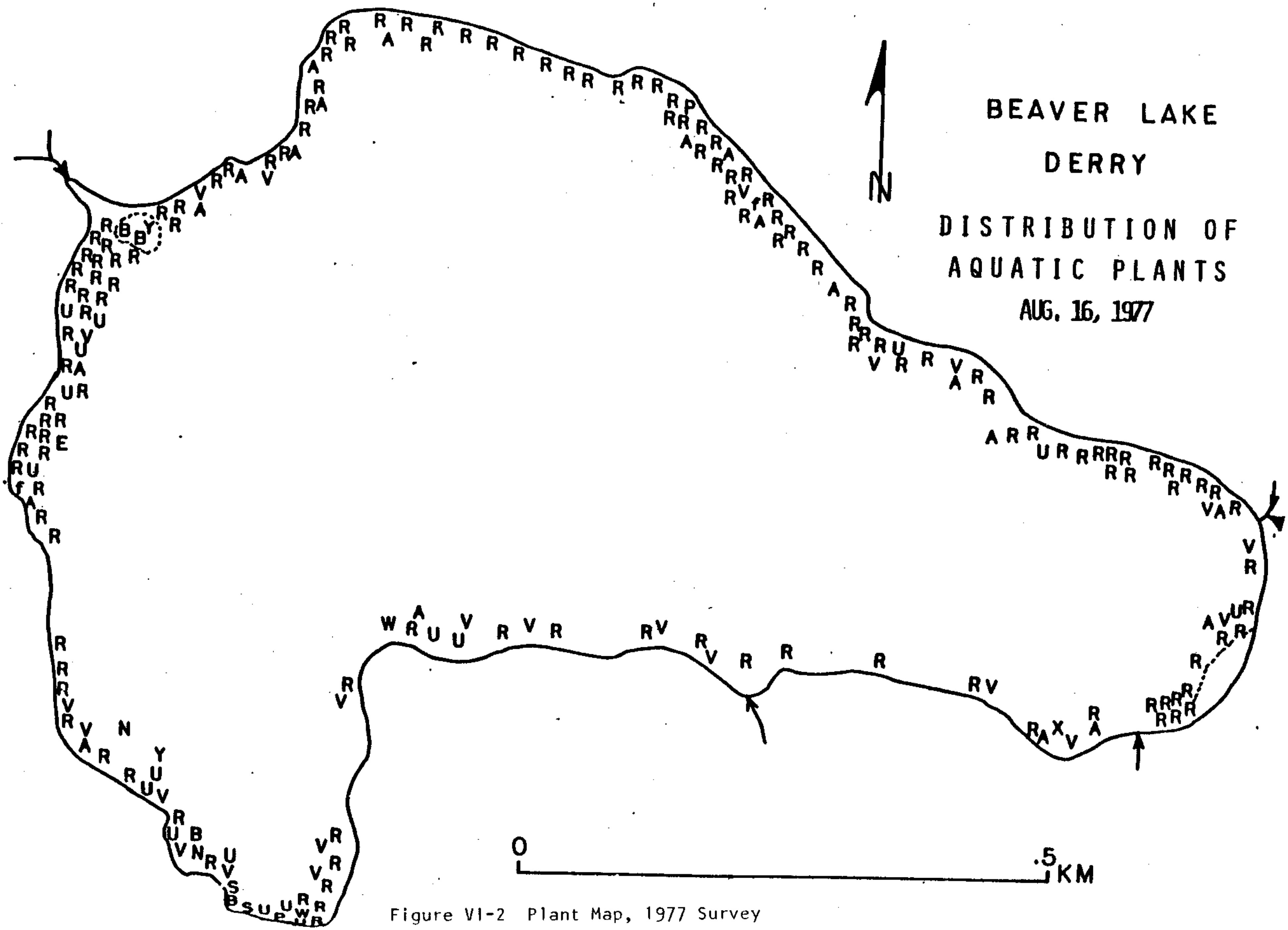


Figure VI-2 Plant Map, 1977 Survey

Table VI-4
Plant Map Key 1977 Survey

AQUATIC PLANT SURVEY

LAKE Beaver Lake TOWN Derry DATE Aug. 16, 1977 BY WSPCC

No.	PLANT NAME GENERIC	PLANT NAME COMMON	ABUNDANCE
R	Potamogeton robbinsii	Robbins Pondweed	Very Abundant
U	Utricularia	Bladderwort	Common
A	Potamogeton amplifolius	Bass Weed	Common
V	Vallisneria	Tape Grass	Abundant
N	Nymphaea	Water Lily	Sparse
Y	Nuphar	Yellow Water Lily	Sparse
B	Brasenia	Water Shield	Sparse
S	Scirpus	Bulrush	Sparse
P	Pontederia	Pickerelweed	Sparse
W	Potamogeton	Pondweed	Sparse
E	Elodea	Waterweed	Sparse
X		Bottom Growth	Scattered
f		Filamentous Algae	Sparse

OVERALL ABUNDANCE Very Abundant

GENERAL OBSERVATIONS:

1. Emergent vegetation was sparse, but submergent vegetation, particularly Potamogeton robbinsii, was very abundant. The submerged vegetation was visible just about everywhere the bottom was visible, except where a sandy beach had been put in. The submerged vegetation probably extends over much of the lake bottom, but the bottom was difficult to see much over six-seven feet.

2. The lake is about 99% developed; it has a past history of some faulty septic systems, but the current bacterial results indicates that is not a problem now.

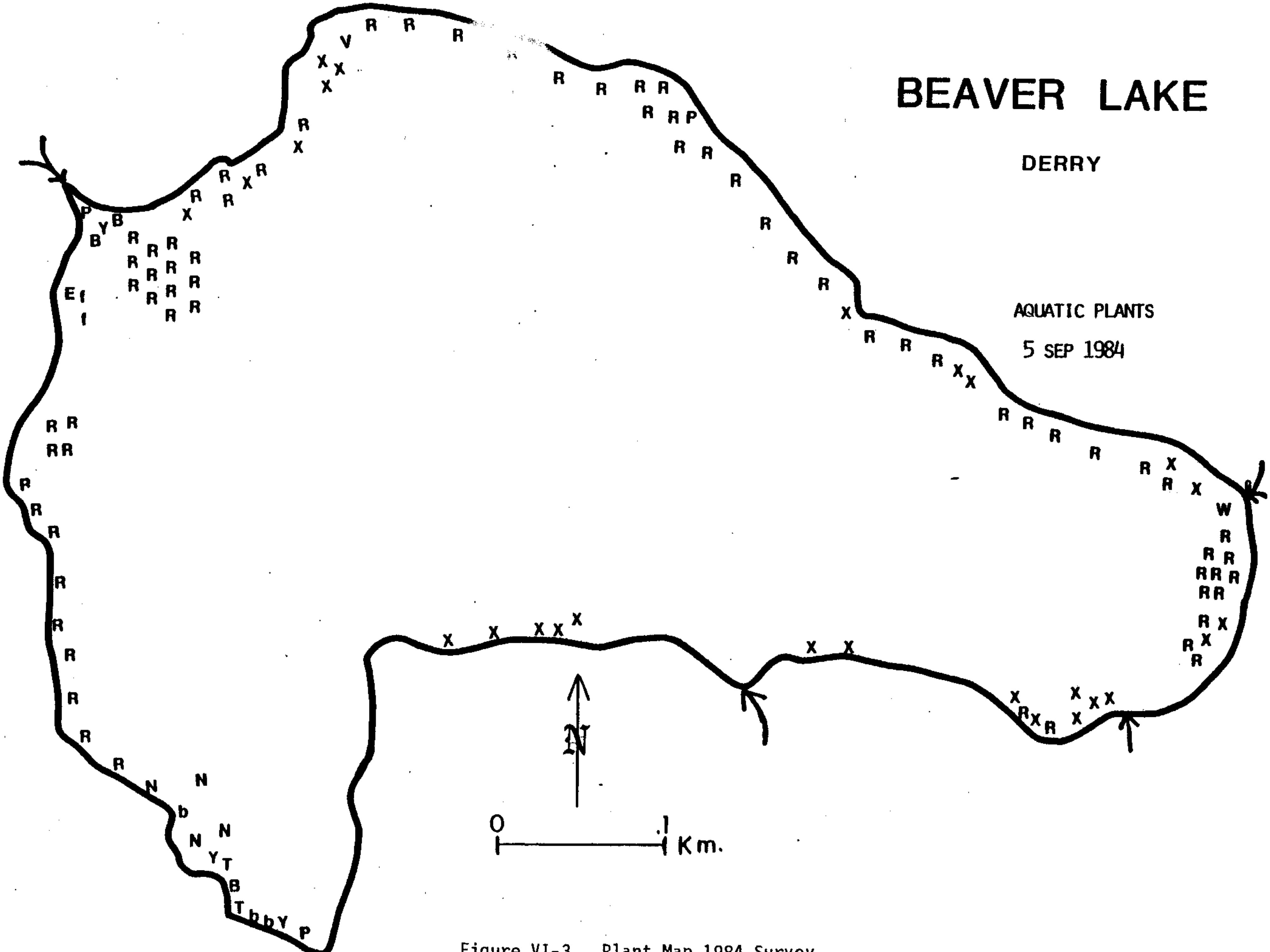


Figure VI-3. Plant Map 1984 Survey

Table VI-5
Plant Map Key 1984 Survey

AQUATIC PLANT SURVEY

LAKE Beaver Lake TOWN Derry DATE 9/5/84 BY WSPCC

Key	PLANT NAME		ABUNDANCE
	GENERIC	COMMON	
R	Potamogeton Robbinsii	Robbin's Pondweed	Abundant
U	Utricularia	Bladderwort	Sparse
T	Typha	Cattail	Sparse
b	Scirpus	Bulrush	Sparse
N	Nymphaea	White Water Lily	Sparse
Y	Nuphar	Yellow Water Lily	Sparse
B	Brasenia schreberi	Water Shield	Sparse
P	Pontederia cordata	Pickerelweed	Sparse
V	Vallisneria americana	Tape Grass	Sparse
E	Elodea	Waterweed	Sparse
X	Potamogeton amplifolius	Bassweed	Abundant
W	Potamogeton	Pondweed	Sparse
f		Filamentous algae	Sparse

OVERALL ABUNDANCE Abundant

GENERAL OBSERVATIONS:

VII. HYDROLOGIC BUDGET

A. Surface and Groundwater Hydrology

The hydrologic budget for a lake equates the total water input to the total water output for specified time increments during a specified period. The water flow rates through the lake are thereby quantified. The development of a hydrologic budget is essential in calculating the loading (mass per unit time) of eutrophying nutrients as well as in evaluating a lake's tolerance of these nutrients. The balance between hydrologic inputs and outputs influence the nutrient supply to the lake, the lake's water residence time, and consequently the lake's productivity and water quality. An accurate and detailed hydrologic budget will thus permit an accurate determination of current trophic status and will provide a sound basis for evaluating the effectiveness of watershed and in-lake management strategies for improving trophic status.

The quantification of the components of the Beaver Lake hydrologic budget was based on an intensive one-year stream gaging and precipitation measurement. A budget for the gaging period (February 1990, through January 1991) was developed as a basis for a complete hydrologic year and phosphorus budget. The budget quantifies the monthly and annual water inflow from each source to Beaver Lake. Additionally, the monthly variations in the lake's hydraulic retention (flushing) time and fraction of exchanged lake water volume are specified.

In conjunction with the hydrologic budget for Beaver Lake, mean monthly surface water discharge volumes for each station in the watershed were calculated and tabulated for the gaging year. This information is valuable for comparing the relative hydrologic (and hence nutrient) contributions from various tributary areas within the watershed. Section B describes the field monitoring program. Section C presents the hydrologic budget and other hydrologic data, and discusses their development.

B. Field Monitoring Program

Field investigations and data collection occurred during the period from November 1989, through August 1991. The actual gaging year budget presented in this chapter encompasses a complete year, beginning February 1, 1990 and ending January 31, 1991.

1. Stream Gaging and Precipitation Monitoring

Nine inflowing tributaries and two outlet stations were monitored for flow within the Beaver Lake watershed. To determine the stage-discharge relationships at each station, measurements of flow were obtained using current meters two or three times per month (depending on time of year and station when flow warranted). Stage-discharge relationships and discharge summaries for each station can be found in Appendix VII-1.

Direct discharge measurements do have some disadvantages. Schroeder (1979) and Dennis (1988) point out that periods of peak discharge during storm events and spring meltoff may be missed, resulting in lower estimates of inflow and thus nutrient loading. In fact, both spring meltoff and storm events could represent a high percent of the total hydrologic and phosphorus budget in a given watershed. To partially offset this disadvantage, specific storm event and snowmelt sampling was conducted during the study.

A variety of methods have been utilized to calculate runoff and water budgets. Each method has drawbacks. Estimates of flow rates on tributary streams from interpolation of flows from neighboring watersheds can have significant errors (Kemp, 1979). Dillon (1974) cautions against predicting water budgets through emperical methods using long-term runoff maps. He suggests that measurement versus estimation provides more accurate results and should be utilized where possible. In general, values will usually fall within 25% of those predicted using long-term runoff maps.

Daily rainfall and water equivalent snowfall data (Chapter III) were collected from NOAA climatological stations in Concord and Manchester, New Hampshire. The Manchester station is within 8 miles from the study area. Monthly rainfall and water equivalent snowfall data for Beaver Lake is presented in Table VII-1, along with the surface volume precipitation upon the lake. Monthly evaporation volume from Beaver is presented in Table VII-2.

2. Groundwater

One area which is poorly understood, and in which little information exists, is groundwater seepage and its nutrient contribution to surface waters. In many cases, groundwater seepage may represent a significant input of water and nutrients to an aquatic system. Recent, as well as past, field work has demonstrated significant interchange between lakes and groundwater

Table VII-1
Beaver Lake Monthly Precipitation Rates

Month	Monthly Total (in)	Monthly Total (M)	Precip (m^3)	Precip ($10^3 m^3$)
1990 Feb	2.55	.06477	35021.14	35.02
Mar	1.48	.037592	20325.99	20.32
Apr	3.82	.097028	52463.04	52.46
May	6.07	.154178	83364.04	83.36
Jun	2.63	.066802	36119.84	36.12
Jul	3.17	.080578	43536.08	43.54
Aug	12.55	.31877	172358.94	172.34
Sep	1.49	.037846	20463.33	20.46
Oct	6.68	.169672	91741.65	91.74
Nov	2.97	.075438	40789.33	40.79
Dec	4.63	.117602	63587.40	63.59
1991 Jan	2.25	.05715	30901.01	30.90
Total	50.29	1.277366	690671.8	690.67

Surface area = 540700m^2
Precip (m^3) = Monthly total (M) x surface area

Table VII-2
Beaver Lake Monthly Evaporation Rates
(pan coef) (Lake surface area) (Monthly Evap)

Month	Total Monthly (in)	Total Mothly M	EV (m^3)	EV ($10^3 m^3$)	EV (Pan Coef)
May	1.70	.04318	23347.426	23.35	18.0
Jun	4.75	.12065	65235.455	62.24	50.2
Jul	4.65	.11811	63862.08	63.86	49.2
Aug	4.73	.12014	64959.7	64.96	50.0
Sep	2.49	.063246	34197.11	34.2	26.3
Oct	1.18	.029972	16705.9	16.2	12.5
Total	19.5	.4953	267808.7	267.8	206.2

(m)(surf) areas   EV(m^3)/1000 x. 77

lenses. Many lakes, rather than being isolated from groundwater bodies by lake bottom sediments, are closely connected with them, forming integral parts of dynamic groundwater flow systems (McBride and Pfankuch, 1975). Nitrogen and phosphorus are direct contributors to the productivity of lakes and streams. These nutrients are often encountered in high concentrations in groundwater and may represent a significant percentage of the nutrient loading to a given lake.

Lee (1972) and Connor (1979) found that seepage flow patterns generally showed an exponential decrease with increasing distance from shore. Shallow groundwater contributes the major volume of seepage to lake.

Downing and Peterka (1978) and Connor (1979) observed that seepage meters collected more groundwater during rainy periods as compared to drier periods occurring during the summer months. It is speculated that as the water table rises due to rainfall, groundwater is forced by the hydraulic gradient into the lake.

Direct measurements of groundwater through the placement of seepage meters can quantify one factor in the hydraulic budget. In the same way, analysis of the seepage can supply important chemical information that can be utilized in nutrient budget calculations.

Groundwater seepage was measured directly in Beaver Lake. Seepage meters were constructed of fifty-five gallon drums (208.2L) cut to form two sections approximately 44cm in height for insertion into organic muck sediments. Sterile bacterial whirl packs, secured to one-holed rubber stoppers in the top of the drum by hard plastic tubing, were used as seepage collection devices (Connor and Belanger, 1981). Meters were placed at single site locations. Five study sites were established within the lake's perimeter (Figure VII-1). Samples were collected from June of 1990 through September 1991.

Seepage rates were measured for the hydrologic budget by occluding the tubing of the collection bag, attaching it to the seepage meter tubing and releasing the occlusion clamp (Figure VII-2). After the measurement interval, the volume of water obtained from the collection device was measured. The seepage rate was calculated by subtracting the initial volume and converting the collected volume (mL) to liters per square meter per day (L/m^2/day). Mean monthly seepage rates for both years were calculated for each of the areas surrounding each seepage meter (Figure VII-1). The areal addition of individual mean annual seepage rates resulted in total groundwater seepage for the entire sediment area of Beaver Lake for the June 1990 to September 1991 period.

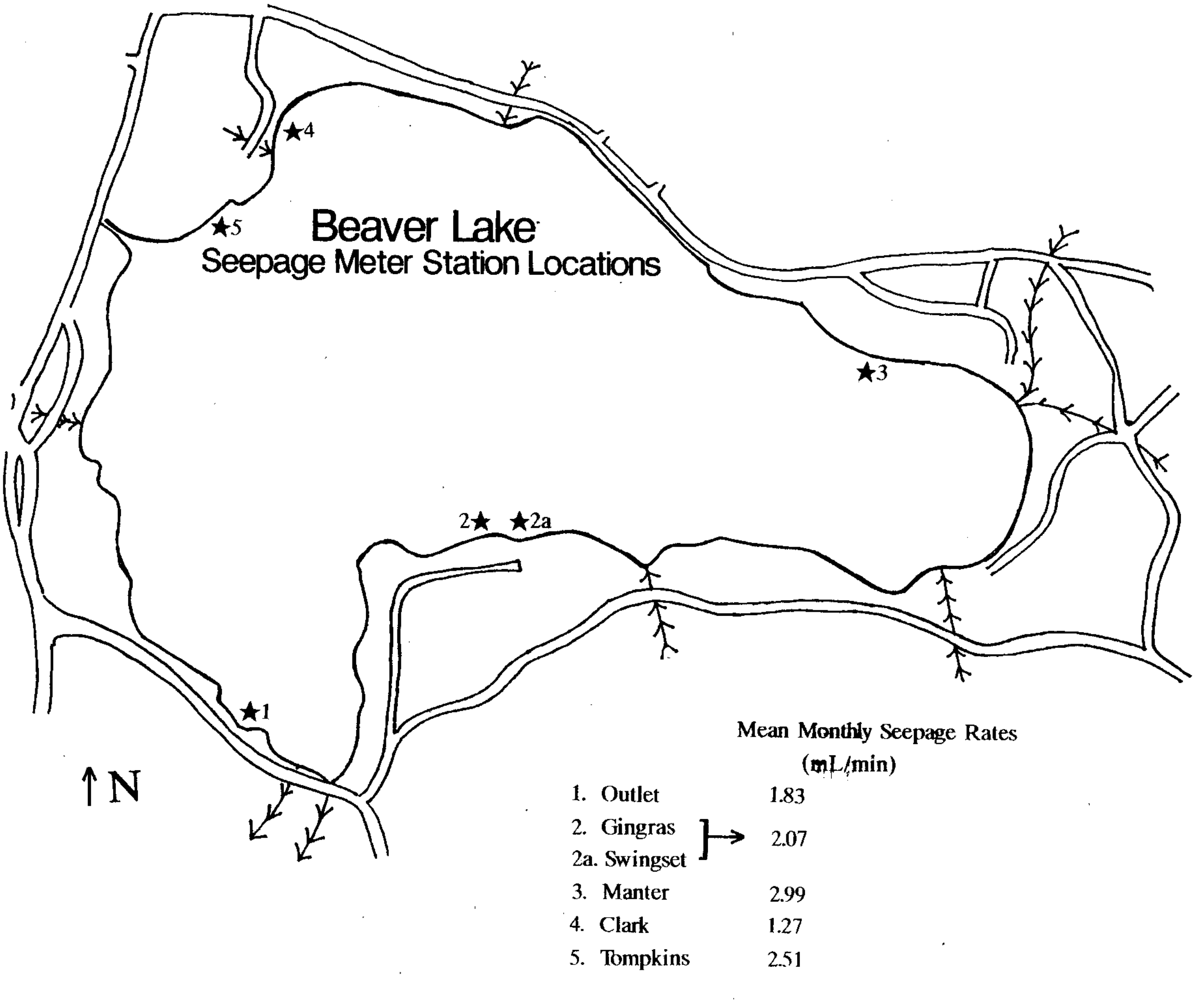


Figure VII-1. Seepage Meter Station Locations

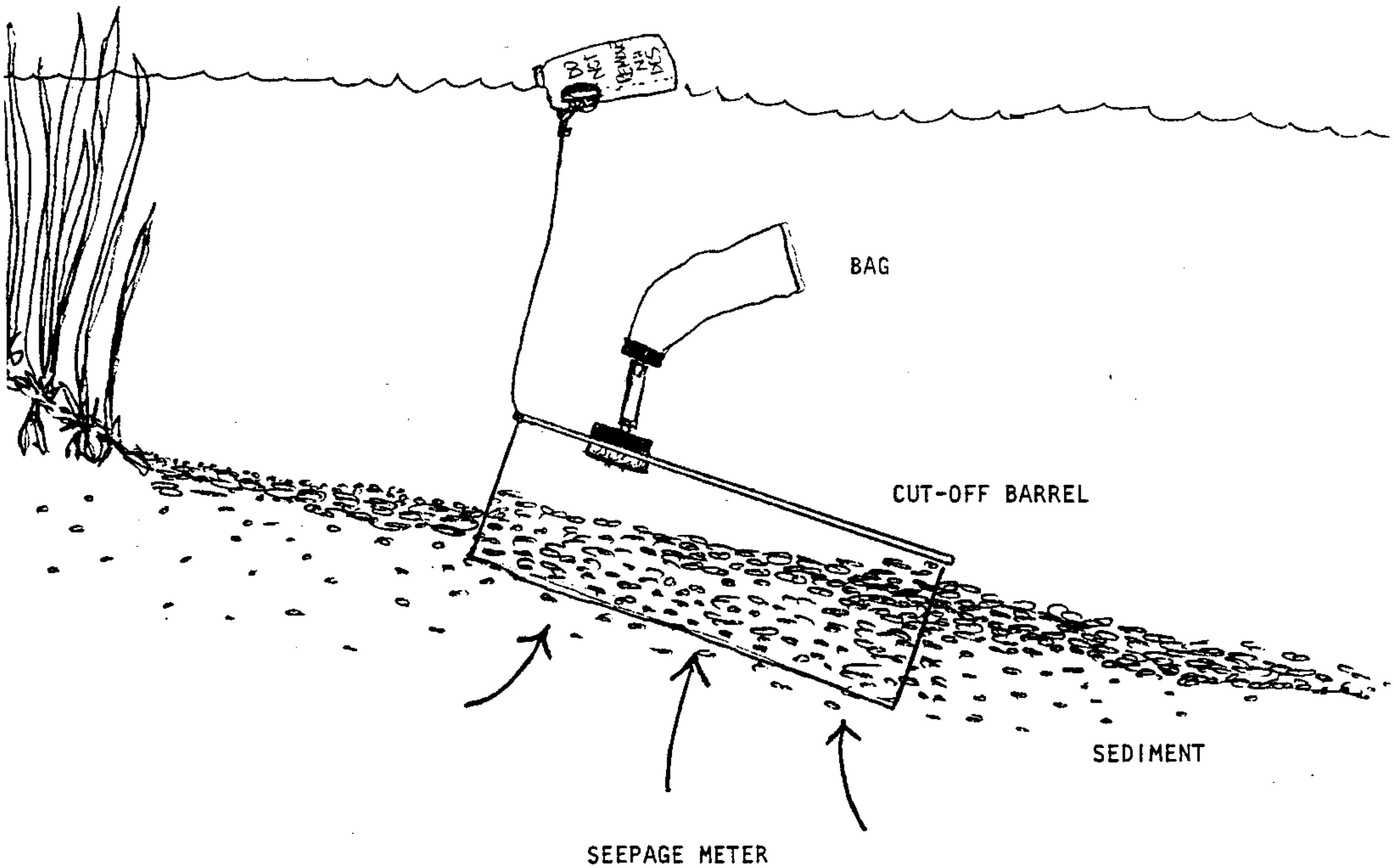


Figure VII-2. Seepage Meter Diagram

Raw seepage meter data, computed from over 100 seepage measurements, are presented in Appendix VII-2.

The greatest seepage rate in Beaver Lake was found at meter three (mean seepage rate = 19 L/m^2/day). Seepage rates were variable throughout the shoreline.

C. Hydrologic Budget Components

The hydrologic budget for the Beaver Lake watershed, equating all measureable inflowing and outflowing waters over a designated period of time, were determined by the following equation:

Inflow volume = outflow volume

Specifically for Beaver Lake

$$Qi_1 + Qi_2 + \ldots Qi_9 + R + P + GWi = Qo_1 + Qo_2 + EV + GWo$$

Where,

Qi1 = Manter Brook

Qi2 = Jenny Dickey Brook

Qi3 = Cat-O-Brook

Qi4 = Cat-O-Swamp

Qi5 = Comeau's Beach Brook

Qi6 = Rte 102 Inlet

Qi7 = Development Brook

Qi8 = Beaver Lake Ave Culvert

Qi9 = Clark Brook

R = Surface water runoff from the direct drainage area

P = Precipitation volume on lake

GWi = Groundwater inflow (seepage)

Qo1 = Outflow (combined lake outflow from dam)

Qo2 = Spillway outflow

EV = Lake surface evaporation

GWo = Groundwater outflow (recharge)

Each component of this budget is in volumetric units of $10^3 m^3$ (1000 cubic meters).

1. Hydrologic Budget for Study Period (1990-1991)

The monthly contributions from the tributaries were derived from the aforementioned stream monitoring stations.

Groundwater seepage (GWi) could have a significant input to a water budget (Connor, 1978). Groundwater seepage was measured directly during the two year study period.

Monthly direct runoff rates (R) were interpolated by multiplying the percent contribution of rainfall by the runoff (m/yr) obtained from the Knox and Nordenson Atlas (1955). This figure was then multiplied by the estimated area around the lake which drained directly from the waterbody.

The total volume of precipitation on a lake (P lake) is the product of the precipitation (meters) times the lake area. Both rainfall and snowfall depths (water equivalents) were collected from records at several NOAA weather stations surrounding Derry (Table VII-1).

Stream outflow (Qo) is the measured discharge from the Beaver Lake outlets. Pan evaporation records for NOAA weather station at Massabesic Lake (Manchester, New Hampshire), were obtained for the study period (Table VII-2). A pan coefficient of 0.77 was selected for the study region from the NOAA Atlas (1979).

Groundwater outflow recharge zones (GWo) are difficult to measure unless reliable seepage meter data, including several meter transects to the deeper portions of the lake, are available. Groundwater recharge was estimated to be a small portion of the water budget. This is because the surrounding groundwater gradients are predominantly oriented into the lake basin, and the zone through which groundwater outflow occurs is small. The hydrologic budget for each month of the study period for Beaver Lake is presented in Table VII-3.

Monthly water volume exchanges are graphically depicted in Figure VII-3, and seasonal values in Figure VII-4.

Table VII-3
Beaver Lake Hydrologic Budget for Gaging Period (Feb, 1990 - Jan, 1991)
Water Volume ($10^3 m^3$)

Component	90 Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	91 Jan	Mean Monthly	Total Annual
Qi_1	937.5	1978.0	1352.8	2007.7	728.2	183.2	260.0	146.4	2164.4	1462.3	1613.1	1459.7	1191.1	14,293.3
Qi_2	102.1	228.7	107.2	273.1	71.2	2.7	11.2	10.7	399.9	336.7	273.1	270.6	173.9	2,087.2
Qi_3	115.0	207.8	144.6	257.9	78.5	51.6	81.2	54.6	316.6	200.0	258.3	291.2	171.4	2,057.3
Qi_4	26.7	39.4	34.5	66.6	24.7	3.8	7.6	10.3	42.6	37.9	33.0	31.4	29.9	358.5
Qi_5	6.9	23.9	13.2	20.5	7.3	0.4	0.7	0.4	26.6	19.1	9.3	24.9	12.8	153.2
Qi_6	0.0	0.0	11.7	0.0	0.0	0.8	0.8	1.5	30.0	14.4	16.2	44.0	10.0	119.4
Qi_7	5.3	14.2	8.1	9.9	4.9	0.0	0.8	0.1	6.8	5.6	6.8	7.6	5.8	70.1
Qi_8	1.9	12.5	2.0	6.3	1.8	0.0	0.4	0.0	5.3	1.7	20.7	3.3	4.7	55.9
Qi_9	0.0	0.0	2.2	2.7	1.5	0.8	0.0	0.0	0.0	1.5	0.8	3.8	1.1	13.3
R	2.5	16.9	16.3	25.7	11.1	13.5	53.5	6.4	28.5	12.6	19.7	2.5	17.4	109.2
P lake	35.0	20.3	52.5	83.4	36.1	43.5	172.3	20.5	91.7	40.8	63.6	30.9	57.6	690.6

Table VII-3
Beaver Lake Hydrologic Budget for Gaging Period (Feb, 1990 - Jan, 1991)
Water Volume ($10^3 m^3$) (contd.)

Component	90 Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	91 Jan	Mean Monthly	Total Annual
GWi	15.0	19.9	48.1	81.3	32.7	41.2	160.0	21.6	89.1	40.5	61.1	15.0	52.1	625.5
Total Inflow	1247.9	2561.6	1793.2	2835.1	998.0	341.5	748.5	272.5	3201.5	2173.1	2375.7	2184.9	1727.8	20,733.5
QO_1	983.9	2075.7	1447.2	2294.0	890.4	237.2	542.8	188.4	2680.8	1834.0	2032.2	1827.4	1419.5	17034.0
QO_2	244.0	465.9	326.0	483.1	37.4	35.1	124.5	55.8	508.2	319.1	313.5	337.5	270.8	3250.1
EV	0.0	0.0	0.0	18.0	50.2	49.2	50.0	26.3	12.5	0.0	0.0	0.0	17.2	206.2
GWO	20.0	20.0	20.0	40.0	20.0	20.0	31.2	2.0	0.0	20.0	30.0	20.0	20.2	243.2
Total Outflow	1247.9	2561.6	1793.2	2835.1	998.0	341.5	748.5	272.5	3201.5	2173.1	2375.7	2185.9	1727.8	20,733.5

Q_i1 – Manter Brook
Q_i2 – Jenney-Dickey Brook
Q_i3 – Cat-O-Brook
Q_i4 – Cat-O-Swamp
Q_i5 – Comeau's Beach Brook
Q_i6 – Rte. 102 Inlet
Q_i7 – Development Brook
Q_i8 – B.L.A.C. Tributary
Q_i9 – Clark Brook

R – Direct runoff
P lake – Atmospheric
GW_1 – Groundwater Seepage
QO_1 – Outlet 1
QO_2 – Outlet 2
EV – Evaporation
GWO – Groundwater Output

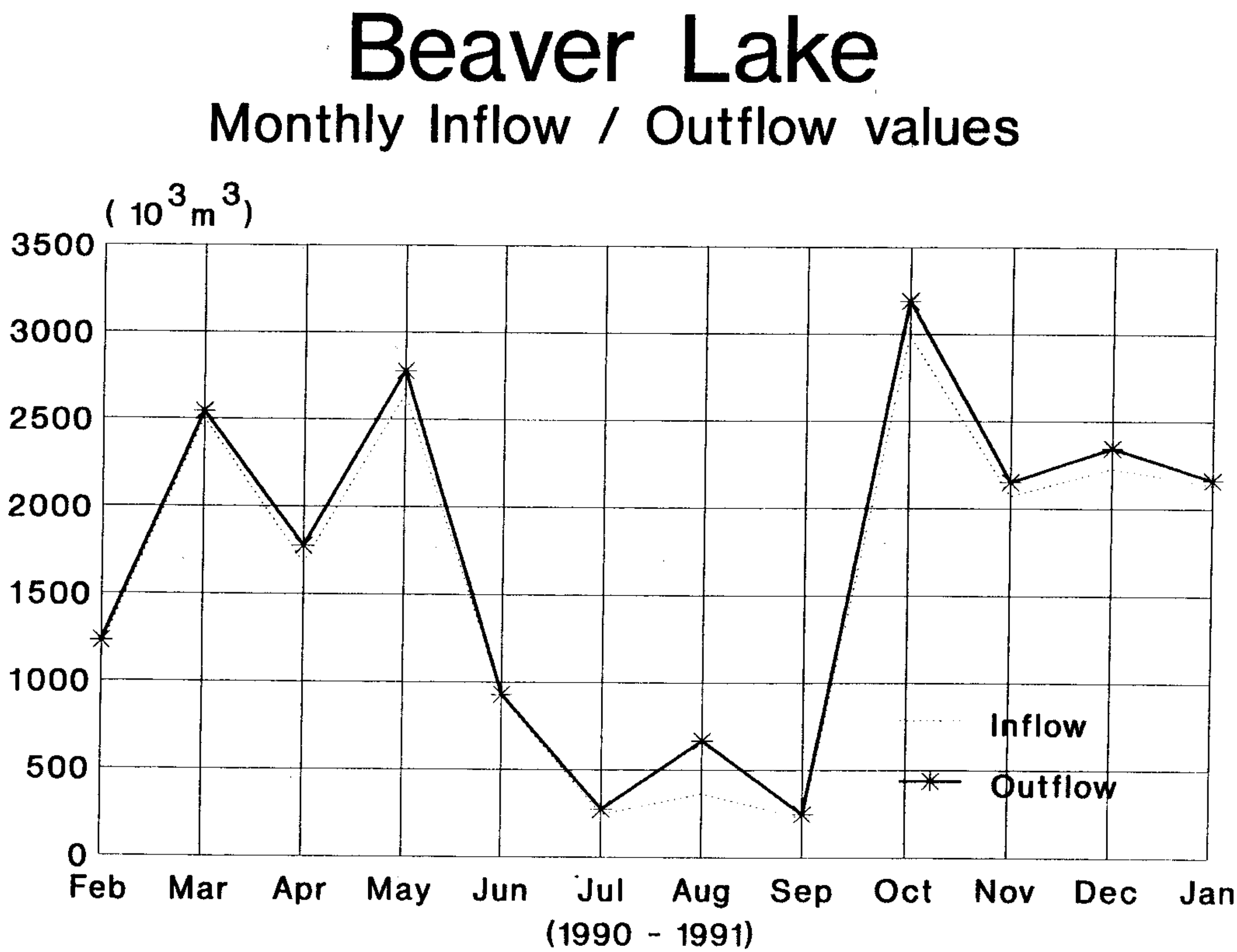
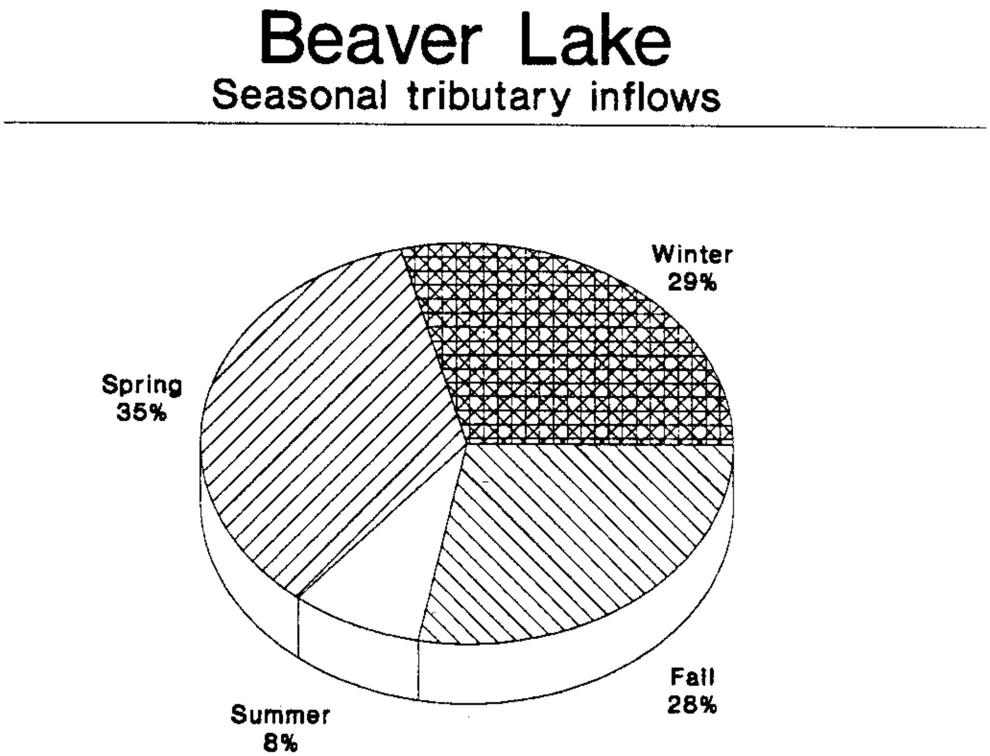


Figure VII-3. Beaver Lake Monthly Water Volume Exchanges



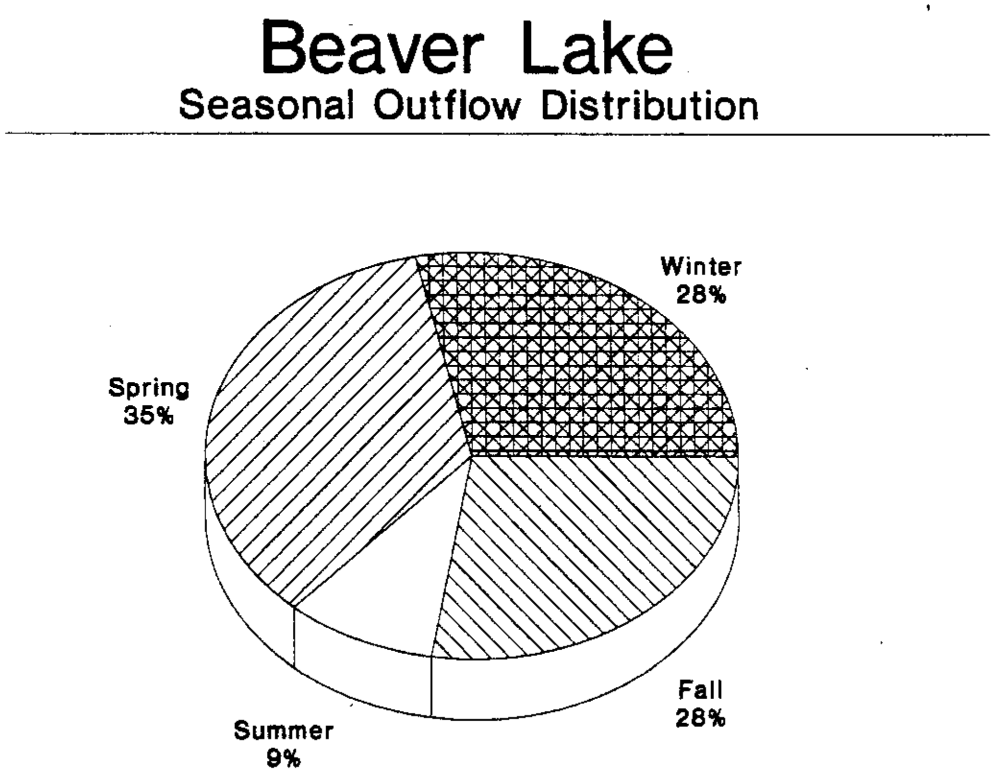


Figure VII-4. Beaver Lake Seasonal Tributary Water Volume Exchanges

Beaver Lake received its highest seasonal tributary inflow during the spring quarter. This season contributed thirty five percent of the annual tributary contribution. Spring flows are generally high due to snowmelt water and fairly high precipitation. The summer months had the smallest contribution accounting for only 8% of the tributary inflow budget. The fall and winter seasons were similar, contributing 28% and 29% respectively.

The seasonal precipitation rates did not follow the seasonal tributary inputs however. The spring, fall and winter months had comparable contributions to the water budget, and accounted for 22.6, 22.2 and 18.8 percents respectively. The season of greatest precipitation occurred in the summer, which was the season of least flows. This was due primarily to two high intensity storm events that occurred during the month of August. Storm events of this type are of relatively short duration and, as such, are difficult to detect by stream monitoring due to the rapid rise and fall of the water.

Another aspect to consider when assessing a storm's significance is the environmental conditions at the time of the storm. August is typically a hot dry month in the Northeast and at the end of the growing season. The land is usually dry, with a low water table, and is primed for absorption of rainfall. These factors may have contributed to the absence of evidence in the inflow data of the high rainfall.

The next highest month in terms of rainfall quantity was October. This correlated well with the tributary inflow data, as it was also the month of highest flow. The rain events during October were more disperse and of much lower intensity than those in August, and thus easier to detect.

Figure VII-5 displays the relative annual volume of each tributary flow to Beaver Lake. Manter Brook, which drains both Harrantis Lake and Adams Pond, contributed 74 percent of the tributary inflow to Beaver Lake. Jenny-Dickey Brook was responsible for 11 percent of the tributary inflow to Beaver Lake. Cat-O-Brook, located on the pond's northwestern shore, was the only other brook contributing ten percent or more of the total tributary inflow to Beaver Lake. The remaining six tributaries collectively made up only four percent of the study year tributary flow.

Figure VII-6 depicts the relative annual volumes of each inflowing component of the hydrologic budget for Beaver Lake. Tributary flow accounted for 19208.9 $10^3 m^3$ of the total 20733.5 flow, or 93 percent of the inflowing water. Both groundwater seepage and direct precipitation represented three percent of the inflowing water to Beaver Lake.

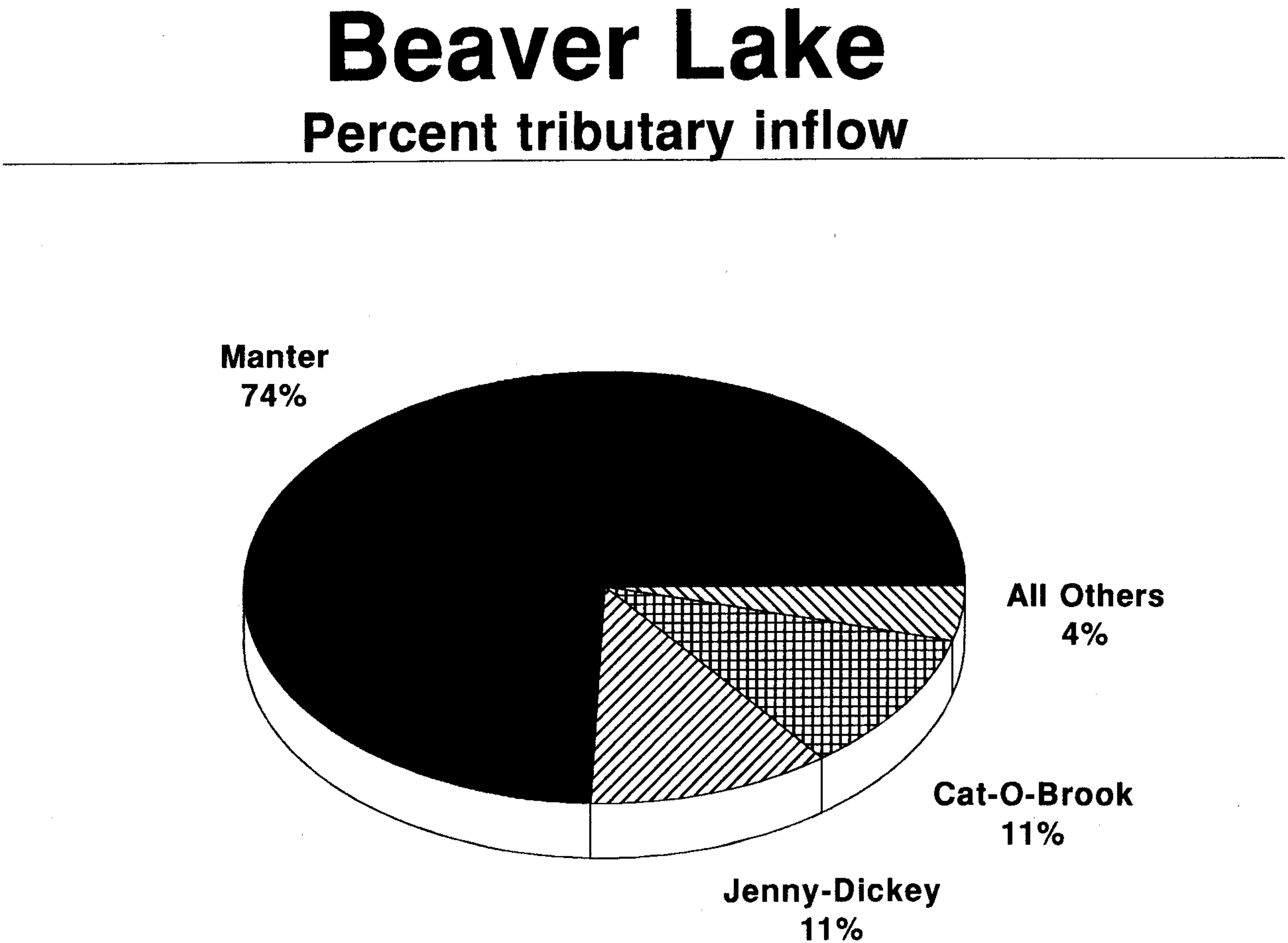
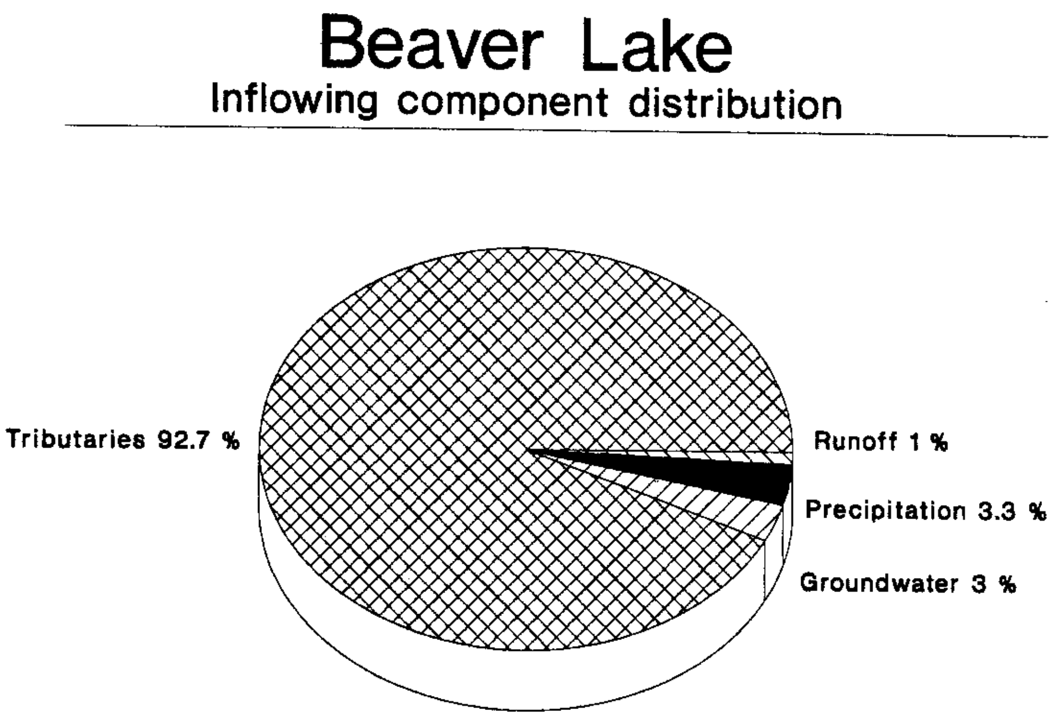


Figure VII-5. Percent Tributary Inflow



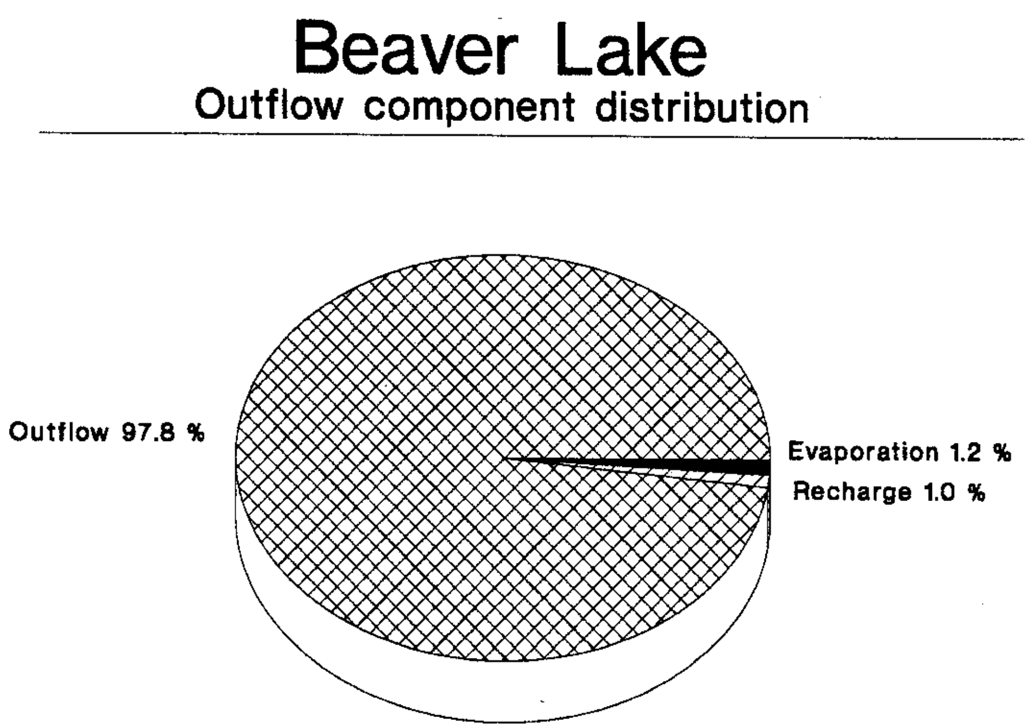


Figure VII-6. Beaver Lake Inflowing/Outflowing Component Distribution

2. Storm Event Hydrology

Stormwater runoff is a principal cause for degradation of rural lakes where agricultural runoff is present (Cooke et. al, 1986). Runoff water will likely contain the impurities in precipitation plus debris and other impurities deposited on the ground surface. Pollutants diffuse over the surface of the land and eventually enter the aquatic system (Wanielista, 1978).

Two types of storm events are important to the hydrologic and nutrient budget. High intensity, short duration storm events can represent a high percent of the total water budget and a significant percent of the phosphorus export to a lake. Since less water is able to percolate into the ground in high intensity storm events, more unfiltered surface runoff and more erosional material is carried to the lake and its tributaries.

The sample year rainfall total for Beaver Lake was 50.29 inches. This is above the 20 year mean for the state, which shows an average yearly rainfall value of 38.07 inches. This increase was due primarily to two high intensity rain events during August, and the notably rainy months of May and October during the study year.

The rain event sampled occurred during August of 1991 with the onset of Hurricane Bob. The area received over 3.82 inches of rainfall during an estimated 8 hour event. All the storm event discharge data are presented in Appendix V-2.

Table VII-4 shows the change of flow and percent change of flow over time for each of the Beaver Lake tributaries. Most of the stations had the greatest increase of flow during the first two time intervals (early in the storm). It should be noted that the beginning of the sampling period occurred approximately an hour after the storm began. One tributary, Jenny-Dickey Brook, showed its greatest increase during the sixth interval. The greatest percent change in flow occurred at Cat-O-Brook during the second time interval. The smallest percent change in flow occurred at the B.L.A.C. tributary during the conclusion of the storm. At that time the B.L.A.C. tributary had recorded a negative change in flow percent. Sample interval maximum peaks occurred at different times for the Beaver Lake tributaries.

For the most part, peak flows occurred after interval seven. The Cat-O-tributaries peak flows could not be determined because of water levels occurring over the top of the staff gage after interval 6 (for Cat-O-Swamp) or interval 7 (Cat-O-Brook).

Table VII-4
Beaver Lake Storm Event Sample Interval Change of Flows (F = CFS)

Interval	1			2			3			4			5			6			7			8			9		
Station	F	ΔF	%	F	ΔF	%	F	ΔF	%	F	ΔF	%	F	ΔF	%	F	ΔF	%	F	ΔF	%	F	ΔF	%	F	ΔF	%
Outlet 1				1.8			2.3	0.5	22	7.3	5.0	68	8.2	0.9	11	13.6	5.4	40	21.8	8.2	38	30	8.2	27	44.8	14.8	33
Outlet 2	6.3			7.6	1.3	18	8.1	0.5	6	8.6	0.6	6	9.2	0.6	6	10.6	1.3	13	11.4	0.9	8	12.6	1.1		14.6	2.0	60
BLAC	1.38			2.6	1.2	47	3.1	0.5	15	3.6	0.5	14	3.7	0.1	3	4.3	0.6	13	4.3	0	0	4.2	0.1	-3	3.2	-1.0	-3.0
Comeau's	.25			0.6	0.3	57	0.7	0.1	19	0.9	0.2	22	1.1	0.2	19	1.3	0.2	13	1.9	0.6	33	2.0	0.1	4			
Jenny Dickey	.28			2.2	2.0	43	3.2	0.6	18	3.8	0.6	16	4.4	1.8	40	6.1	3.0	49	9.2	3.3	36	12.5	3.3	3	15.6	3.2	20
Manter	3.55			10.8	7.3	67	16.3	5.4	33	22.3	6	27	32.4	10.1	31	46.5	14.1	30	75.0	28.5	38	101.6	26.7	26	227.4	125.8	55
Dev.	.06			0.2	0.1	63	0.3	0.1	43	0.4	0.1	28	0.4	0	9	0.8	0.4	48	1.2	0.4	32	1.4	0.2	16	0.8	-0.6	-0.8
Cat - O - Swamp	.72			1.7	1.0	57	2.0	0.4	18	2.6	0.5	20	3.3	0.7	21	+3.7	* +0.4	+12									
Cat - O - Brook	.53			1.7	1.2	69	2.4	0.7	30	3.4	1.0	29	5.2	1.7	33	8.4	3.2	38	+25.6	* +17	.2+67						

*not actual flows, water above top of gage
F = flow in cubic ft/second
ΔF = change in flow for time interval
% = % change in flow for time interval

Twenty five percent of the precipitation occurred during August. Direct surface runoff accounted for one percent of the total component budget. In most cases, much of the direct runoff occurs in March and April when the ground is impermeable to water because of its frozen condition, and snowmelt is at its maximum peak. By late spring through mid fall, the ground has the capacity to contain or absorb much of this rain water, especially in low and intermediate storm events. Direct runoff values were highest during the months of August, October and May, as were precipitation values.

Groundwater seepage rates were measured at 5 sites along the shore of Beaver Lake. Past research has show that seepage rates increase near shore after rainfall events. On a seasonal basis, groundwater seepage rates increase during late spring with the replenishment of the water table with snowmelt. The summer months reflect lesser seepage rates but are more variable due to summer storm events. Seepage rates tend to rise during the usually wet New England fall season. The winter months usually reflect lower seepage as a result of frozen ground and snowfall as opposed to rainfall.

High seepage rates during the study year varied by station. Both the outlet station and Manter Brook station had high values during June, while the remainder of the stations had elevated values during August. Different patterns of seepage were measured during a subsequent sampling season. Three of the stations had elevated flow averages in September. This may be due to the late August storm event of Hurricane Bob and its significant water input to the system. One station had a maximum value in August while the outlet station's greatest value occurred again in June.

Figure VII-6 compares the hydrologic outflow components of Beaver Lake. Water flowing from the lake via outlet structures accounted for 98 percent of the total discharge volume at Beaver Lake.

Evaporation depleted one percent of the water leaving Beaver Lake. The summer months accounted for 72 percent of the evaporated water portion. Groundwater recharge was estimated to be only one percent of the total discharge volume from Beaver Lake.

The outlet discharge data trails the tributary data for peak flow intervals, having maximum discharge values during the last sampling interval. The greatest percent change of flow occurred at different times in the outlet samples. Outlet 1 had its greatest change during interval four, while this occurred in outlet two during interval eight. Percent change in flow was greater in both outlets than any tributary, as would be expected.

Table VII-5 reflects the storm event's peak flow data. Turbidity and fecal coliform results are discussed in Chapter 6. Total phosphorus results are discussed in Chapter 8. Raw data can be found in Appendix VI-2.

Low intensity, longer duration, events can also be significant to the hydrologic budget but usually have a lesser impact to the nutrient budget. More water infiltration to the ground allows less direct surface drainage into an aquatic system. Low intensity rain events do increase groundwater seepage rates in the lake and tributaries (Connor, 1979); however, the lake quality impacts in reference to erosion and phosphorus exports are less severe than a high intensity event.

Table VII-5
Storm Event Peak Flow Times and Discharge
For Each Station

Station	Time	Discharge (CFS)
Outlet 1	5:00pm	44.81
Outlet 2	5:00pm	3.39
B.L.A.C.	4:00pm	4.26
Comeau's	4:30pm	2.01
Jenny-Dickey	5:00pm	15.65
Manter	5:00pm	227.43
Development	4:30pm	1.45
Cat-O-Swamp	4:30pm	>25.58
Cat-O-Brook	4:30pm	>3.71

CHAPTER VIII

VIII. PHOSPHORUS BUDGET

A. Development of Phosphorus Budgets

The calculation of a phosphorus budget is an essential step in the evaluation of a lake's trophic status. A phosphorus budget provides a means to evaluate and rank phosphorus sources that may contribute to algal problems. It is most important to realize the quantity of nutrients (especially phosphorus) entering the lake, as well as the ultimate fate of those nutrients. The phosphorus budget relies heavily upon the accuracy of the hydrologic budget for its input and output variables.

Many extensive nutrient budgets have been reported in the literature. Lake Washington in Seattle, Washington (Edmondson, 1972), Lake Erie (Burns, 1970), and Kezar Lake, North Sutton, New Hampshire (Connor and Smith, 1983) have been studied in great detail.

Nutrient loading rates have been reported as either "surface loading rates" or "volumetric loading rates" and are usually expressed in terms of mass per unit area-time, or mass per unit volume-time.

The purpose of this chapter is to quantify the various avenues of phosphorus inputs into Beaver Lake and to explore the various phosphorus sinks and exports from the watershed. Phosphorus loadings (flux) were calculated for each tributary inflow, outflow, direct runoff, atmospheric, groundwater, and septic leachate to Beaver Lake. A phosphorus budget was then prepared for the 1990-91 study year.

B. Phosphorus Budget Components

1. Tributary loading and discharge

Tributary phosphorus concentrations were analyzed and monthly loadings were calculated for each of the Beaver Lake stations. Tributary phosphorus loadings to Beaver Lake were tabulated during the twelve month study period. Phosphorus loadings were determined by calculating mean monthly tributary flows ($10^3 m^3$) and multiplying these values by mean monthly phosphorus concentrations (mg/L). The resultant values represent mean monthly phosphorus loading or flux (Kg P). The summations of each of the calculated monthly values equals the total tributary annual phosphorus loading.

Table VIII-1 shows the monthly tributary phosphorus load to Beaver Lake. Manter Brook contributed 238 Kg of phosphorus to Beaver Lake during the 90-91 study year, or 68 percent of the tributary phosphorus load. Jenny Dickey Brook provided 54 Kg of phosphorus or 16 percent of the total tributary loading. The third greatest phosphorus producer was Cat-O-Brook which donated 35 Kg and 10 percent. Each of the other trubutaries combined, contributed approximately 6 percent of the tributary budget.

2. Atmospheric

Atmospheric inputs consist of two major components: (1) wind transported material, commonly referred to as dryfall, removed from the air by sedimentation or impaction; and (2) soluble gases or salts that are scavenged by rainfall. Estimates for the dryfall portion alone may be as high as 70-90 percent of the total atmospheric load (Likens and Loucks, 1978).

In agrarian areas, increases in nutrient loads transported via the atmosphere can be attributed to agricultural activities and associated soil disturbances. Urban atmospheric inputs of nutrients can be attributed primarily to combustion emissions.

Atmospheric phosphorus loading (wetfall and dryfall) for Beaver Lake was determined by the direct measurement of phosphorus in rain samples collected in Concord, New Hampshire, while dryfall was calculated utilizing dryfall export coefficients (Reckhow, et al, 1980). The measured mean phosphorus concentration calculated for the sample season was then multiplied by the monthly rainfall and the lakes surface area to obtain the phosphorus loading to the lake. The atmospheric phosphorus contribution to Beaver Lake during the study period was 25 Kg with a mean monthly load of 2.1 Kg. Since the phosphorus load from atmospheric deposition is dependent on annual weather patterns, the greatest phosphorus contributions occur during the wettest seasons. This will be discussed in greater detail in the phosphorus budget sections. The month of August contributed 24 percent of the total annual atmospheric phosphorus loading to Beaver Lake.

3. Direct Surface Runoff

Direct surface runoff includes the water and its transported phosphorus that does not enter a lake via tributary or groundwater. Direct surface runoff is the result of near shore snowmelt and rainfall, especially during high intensity storms.

TABLE VIII-1
Tributary Phosphorus Loading to Beaver Lake
During Study Year

Tributary	Flow Volume (10^3M^3)	Mean P Conc. (ug/L)	P Load (Kg)	% of Total
1. BLAC	55.9	31	1.1	--
2. Comeau's	153.2	18	2.6	1
3. Jenny Dickey	2,087.2	23	54.4	16
4. Manter	14,293.3	19	237.5	68
5. Development	70.1	132	8.4	2
6. Clark	13.3	58	0.8	--
7. Cat-O-Brook	2,057.3	21	35.1	10
8. Cat-O-Swamp	358.5	19	7.4	2
9. Rte. 102	119.4	26	2.2	1

Loadings in runoff from shoreline areas can be estimated indirectly. In many cases, indirect estimates of loading from an area can be derived from information on watershed characteristics. This method is based on the concept that two watersheds in the same region and with similar land use patterns and geology will tend to contribute the same loading of phosphorus per unit area. This permits extrapolation of data from one or more monitored watersheds to others.

Shoreline runoff areas at Beaver Lake were designated as mixed forest and urban low density residential. Table VIII-2 shows the selected export coefficient and total phosphorus export for each watershed designation. To obtain the direct phosphorus runoff contribution to Beaver Lake, the designated land use areas that did not drain into a monitored tributary were determined. A phosphorus coefficient for each land use was selected by matching similar land uses at Beaver Lake to those with a known phosphorus export. The direct phosphorus runoff was calculated by multiplying the land use area by the phosphorus coefficient.

Increased phosphorus load to a lake from direct runoff corresponds to the area's weather patterns. Periods of frozen ground, snowmelt, and high intensity rainstorms usually contribute an increased phosphorus load via runoff.

Direct runoff contributed 32 Kg of phosphorus to Beaver Lake during the study period. The mean monthly phosphorus contribution to Beaver Lake was 2.7 Kg during the study year.

TABLE VIII-2
Beaver Lake Watershed Phosphorus Export

Watershed Designation	Percent	Area (ha)	Export Coefficient (Kg/ha/yr)	Phosphorus Export (Kg)
Forested/Mixed	20	8.4	0.20	1.7
Urban/Low Density Residential	80	33.7	0.90	30.3

4. Septic Leachate

Septic tanks and leachfields are another non-point source that must be considered as a nutrient source because of their potential for nutrient enrichment of the groundwater which flows into a lake.

Several studies (e.g., Jones and Lee, 1977; NHWS&PCC, 1975) have indicated that a properly designed, constructed, and maintained system will not generally contribute significant amounts of phosphorus to surface waters. However, because of their use in unsuitable areas or because of improper design, construction, or maintenance, it is estimated that over one-half of the systems in use today fail before their designed life of fifteen to twenty years is completed (Scalf *et al*., 1977).

The most common type of individual disposal system is the septic tank-leach field system. The tank functions to separate the solids, both floating and settleable, from the liquid material. The accumulated sludge should be pumped out every three to five years. The liquid is discharged from the tank through piping material and distributed over the leaching area, which is designed to absorb the effluent and to remove the impurities before it percolates to the groundwater.

In 1967, the New Hampshire legislature enacted a law to protect water supplies from pollution by subsurface disposal systems, and directed the Water Supply and Pollution Control Division to establish minimum, state-wide requiremens for properly designed systems. The information required to estimate the phosphorus loading from septic systems is:

1. Location of the system with respect to the surface water body,
2. Soil permeability: the rate of water transmission through saturated soil, of which estimated soil retention coefficients varied with different lake sections,
3. Land slope: steep slopes may cause erosion problems when associated with soils of low permeability,
4. System age: soils have only a finite capacity for phosphorus absorption,
5. Per capita occupancy: (household population based on sanitary survey).
6. Fraction of year system is in use: (i.e., summer cottages or year-round dwellings), and
7. Additional water utilizing machinery: (i.e., washing machines, dish washers, or garbage disposals).

The Town of Derry was in the process of sewering the shoreland area of Beaver Lake during the study year. The septic systems were still functional during the study period but most, if not all, are now on-line to a municipal wastewater treatment facility. The septic tanks of these on-line houses have been pumped dry and either filled or crushed. This scenario creates problems when quantifying the phosphorus budget because phosphorus loading from septic systems occurred during the study year but septic loading has probably decreased significantly since the study year.

The phosphorus input from septic systems was estimated by calculating the septic load before sewering had occurred. Once the total septic phosphorus loading was determined during the study year it was estimated that 25 percent of the total load will still be leaching into the lake. Despite the sewering efforts, we cannot overlook the probable phosphorus load that is occurring from saturated leachfields. The accumulative years of phosphorus saturation to the leachbed soils will likely continue to provide a lesser source of phosphorus to the lake for many years. This process is known as response time.

In most Diagnostic/Feasibility Studies, a survey of individual sanitary waste-disposal systems around the lake is conducted by the Water Supply and Pollution Control Division. The survey consists of a visual inspection of the property, interviews with residents to discuss various problems, and the compilation of certain statistical information regarding the system, such as type of system, age, maintenance schedule, depth to groundwater etc. A sanitary survey was not conducted at Beaver Lake due to the aforementioned sewer project.

The amount of phosphorus contributed to Beaver Lake in a given year by subsurface disposal systems was determined by the following equation:

$$\text{Kg P year}^{-1} = (\text{Kg P Capita}^{-1}\ \text{year}^{-1})\ (\#\ \text{homes})$$
$$(\#\ \text{Capita house}^{-1})\ (\#\text{years})\ (1\text{-soil retention coefficient})$$

Permanent home phosphorus loading was calculated by designating 85 living units as year-round homes. It was estimated that on the average, 2.5 persons occupy year-round homes. Since the soils are considered severe and because of the short depth of soil to groundwater, a 0.2 was assigned as the Soil Retention Coefficient. Permanent homes contributed 170 Kg phosphorus for the study year.

Seasonal home phosphorus loading was determined utilizing 33 as the number of seasonal cottages. It was estimated that 3.5 persons occupy seasonal cottages for a 100 day period. Seasonal homes contributed 20 Kg phosphorus over a 100 day period. It was assumed that the permanent homes had washing machines and the seasonal homes did not and therefore the permanent homes contributed more phosphorus per capita. The total phosphorus load to Beaver Lake from septic systems was estimated to be 190 Kg P/year. Because of the sewering a best practical judgement of 25 percent of the total load or 48 Kg P/yr was utilized in the phosphorus budget. Appendix VIII-1 presents the Beaver Lake first tier home analysis used for these calculations.

5. Groundwater

Relatively little is known of groundwater seepage nutrient concentrations and their importance to nutrient budgets. Lee (1977) first applied the direct seepage meter technique in Lake Sallie, Minneosta, in an attempt to monitor the contribution of nutrients from septic tanks located around the lake. He concluded that all septic tank phosphorus appeared to be bound to the soil, but that 40 percent of the nitrogen from the septic tanks entered the lake. In the past, well water along the lake's boundary was analyzed for an estimate of nutrient input via seepage. The utilization of this type of methodology, however, does not account for nutrient concentration differences within the water table profile and does not include sediment interactions with seepage water (Connor, 1979).

A great deal of emphasis was placed on groundwater sampling and analyses for the Beaver Lake project. However, only the interstitial pore water was utilized in calculating the groundwater phosphorus component of the nutrient budget. A list of each of the groundwater monitoring programs conducted at Beaver Lake and a summary of the analyses is provided below.

a. Groundwater Seepage

A series of six seepage meters were placed throughout the shoreline area of Beaver Lake. No chemical analyses were performed on seepage meter water because interstitial pore water samples were being analyzed. A discussion on seepage meters and Beaver Lake groundwater seepage rates is included in the hydrologic budget chapter.

b. Shallow Dug Well Analyses

A series of shallow dug wells were sampled at different locations along the Beaver Lake shoreline. The samples were analyzed for phoshorus concentration. The shallow well phosphorus concentration results were compared to other groundwater sample sources. Well depth ranged from a minimum of 12 feet to a maximum depth of 40 feet.

Phosphorus concentrations were significantly lower in the shallow wells than phosphorus concentrations measured in the interstitial water. The phosphorus concentrations ranged from a minimum of <1 ug/L to a maximum of 33 ug/L. The mean phosphorus concentrations and ranges for the shallow wells can be found in Table VIII-3, and raw data can be found in Appendix VIII-2.

c. Interstitial Pore Water

A specially designed interstitial pore water sampler (IPWS) (Figure VIII-1) was utilized in this study to collect interstitial water. The IPWS was placed in the sediment while interstitial water was pumped through a fine screen and into a sample bottle. Figure VIII-2 shows the location of each station on Beaver Lake that interstitial water was sampled.

Table VIII-4 is a summary of the chemical analyses performed on the interstitial water. Appendix VIII-3 lists all the results collected throughout the study period.

Table VIII-4
Beaver Lake Interstitial Pore Water Analysis

Location	Mean TP (ug/L)	Mean Cond. (umhos/cm)	Mean Cl (mg/L)
Outlet	136	298.4	82.5
Gingras	216	199.2	15.8
Manter	152	161.9	6.5
Clark	285	293.7	29.2
Tompkins	132	114.7	10.8

Table VIII-3
Mean Phosphorus Concentration
and Range for Shallow Wells

Location	Mean TP ug/L	Range
1) 5 North Shore Rd	8	2-13
2) 14 North Shore Rd	<1	<1
3) 55 North Shore Rd	11	5-18
4) 57 North Shore Rd	13	12-14
5) 14 Coles Grove Rd	30	28-33
6) 16 Coles Grove Rd	15	15
7) 24 Coles Grove Rd	14	14
8) 77 Chester Rd	6	3-9
9) 65 Chester Rd	8	8
10) 1 Lake St	2	<1-3
11) 18 Beaver Lake Ave	23	18-27
12) 64 Beaver Lake Ave	11	11
13) 7 Lake Shore Dr	5	5
14) 3 Jenny Dickey Ln	3	3

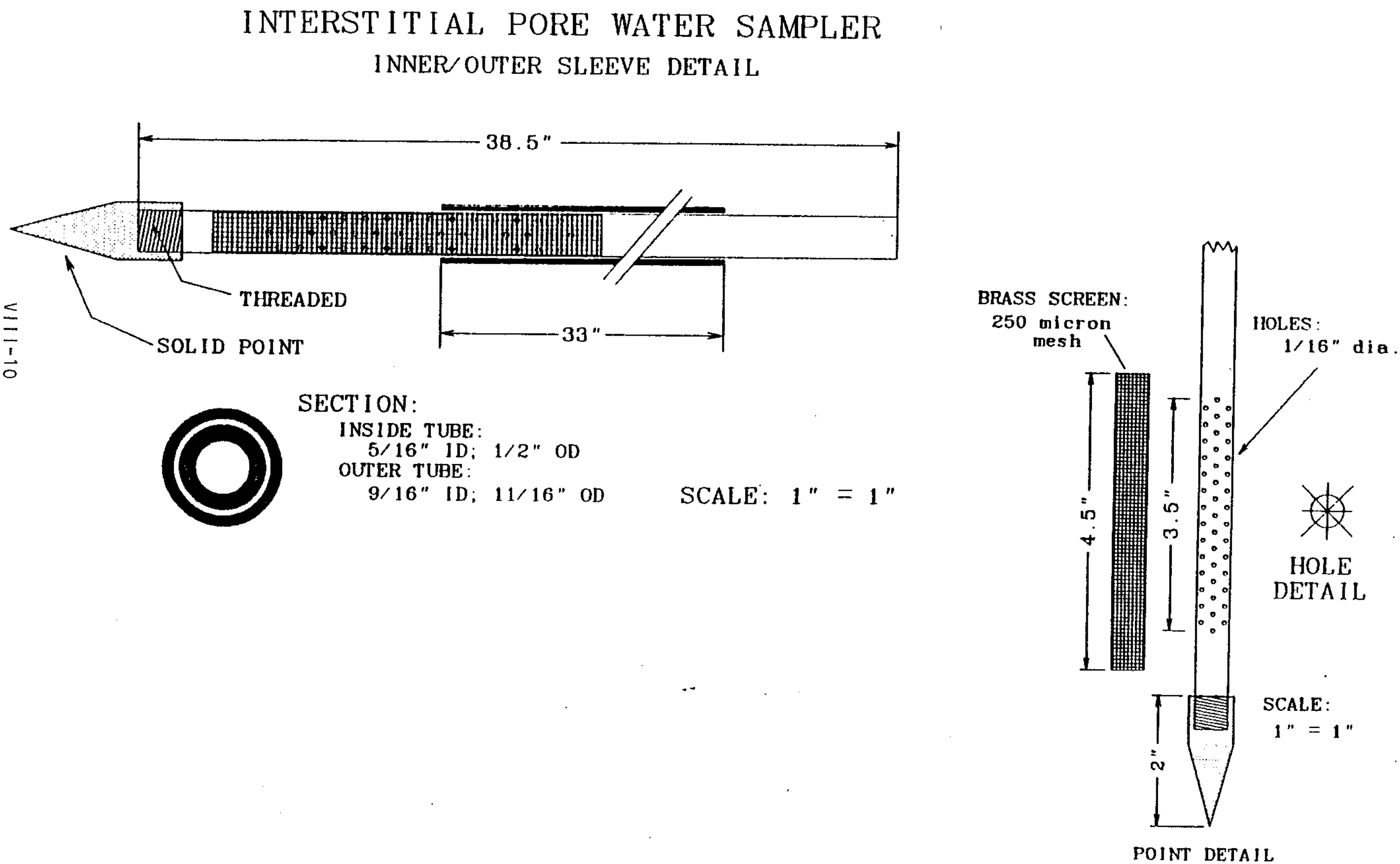


Figure VIII-1. I.P.W.S. Sampling Apparatus

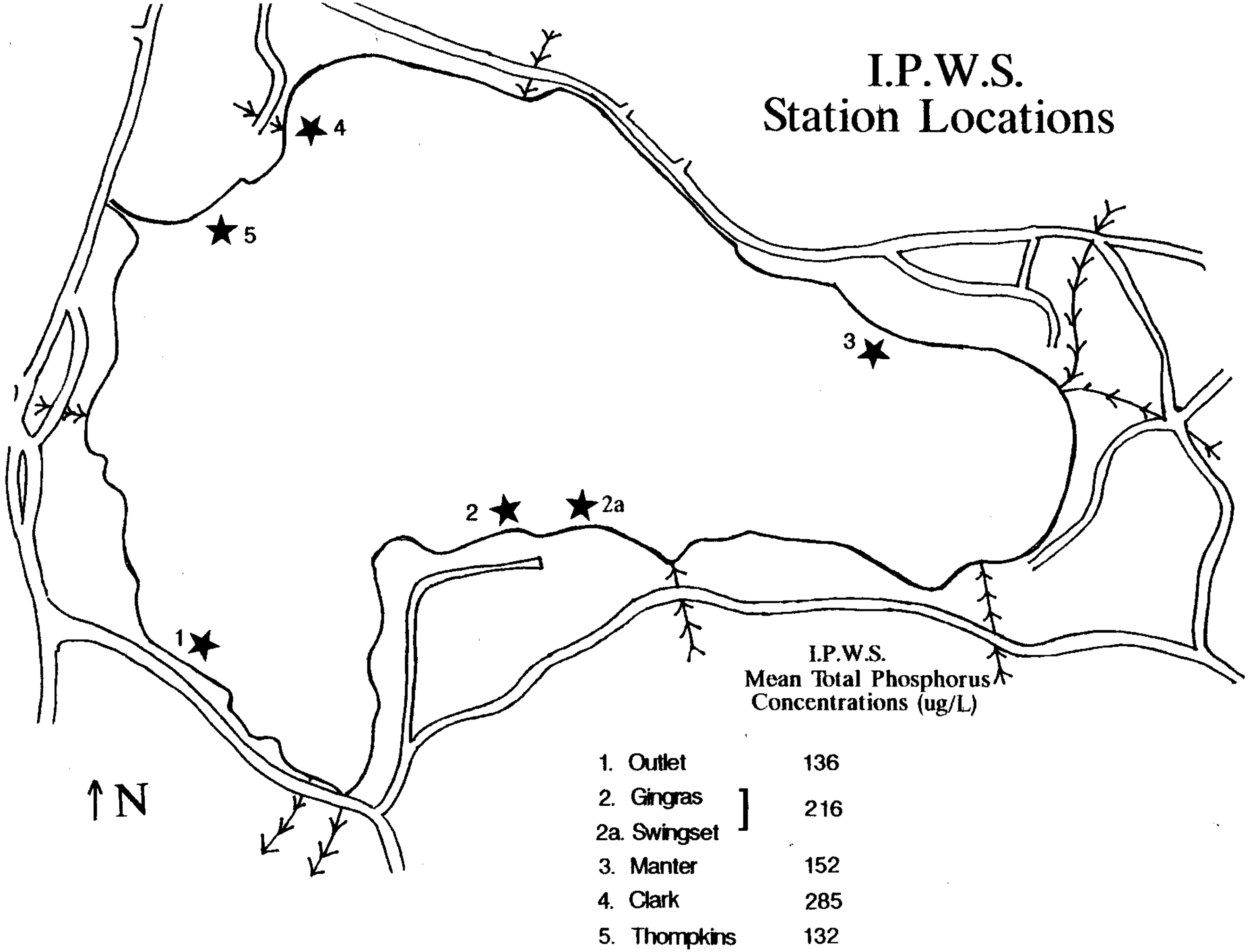


Figure VIII-2. I.P.W.S. Station Locations

The conductivity of interstitial pore water was generally higher than that measured in the surface water. The mean of conductivity measured throughout the sampling sites ranged from a minimum of 115 umhos/cm at station 5 to a maximum conductivity of 298 umhos/cm measured at site 1.

Interstitial pore water phosphorus concentrations were significantly higher than shallow well water phosphorus and hypolimnetic surface water phosphorus. Interstitial water phosphorus ranged from a minimum concentration of 132 ug/L at site 5 to a maximum concentration of 285 ug/L at site 4.

The seepage phosphorus contribution to Beaver Lake was derived from calculating the mean of the mean interstitial phosphorus concentrations obtained during the study period throughout the pond. The seepage rate calculated for the hydrologic budget and the measured mean phosphorus concentrations from the interstitial water reflect the total loading of groundwater seepage to the pond. Seepage loading varied with the monthly seepage rates to Beaver Lake.

d. Groundwater Summary

Several groundwater sources were sampled throughout the Beaver Lake study. These groundwater sources included well water from drinking water sources around the lake, and interstitial water from the sediments of Beaver Lake. Although the results showed that the dug wells surrounding the pond had low phosphorus concentrations, only the interstitial phosphorus analyses were utilized to calculate the phosphorus loading component to the budget. The groundwater interacts with the phosphorus rich sediments and may interact with septic leachate water, contributing to higher amounts of phosphorus in the interstitial water. It is the interstitial water which more accurately reflects the phosphorus load to the lake via groundwater seepage.

6. Sediment Release-Uptake

The fate of phosphorus in water is usually considered to consist of chemical, physical, or biological transformation of the ionic form into a particle, sedimentation of this particle to the bottom, particle breakdown in the sediment, and the release of some of the ionic phosphorus back into the lake water if conditions are favorable.

The actual measurement of total phosphorus release or uptake from the sediment is an impractical task to attempt. Since sediment release and uptake are occurring simultaneously in different sections of a lake, and other chemical, physical and biological activities are also occurring, it is virtually impossible to estabish a realistic total phosphorus release or uptake figure. However, an estimation of net differences between total uptake and total release can be derived by calculating an internal phosphorus loading model. A positive mass balance solution represents net phosphorus release (loading) and a negative solution represents net uptake.

a. Internal Phosphorus Cycling

An essential component of the nutrient budget is the monthly net release or uptake of phosphorus from or to the lake sediments. In order to quantify this component, a phosphorus mass-balance equation was solved for each month of the sample period. Thus, by knowing the masses of phosphorus entering the lake and flowing out of the lake and the change of mass in the lake, the equation can be solved for the mass released or adsorbed by the sediments.

Mass is calculated as the product of concentration and volume. Table VIII-5 shows how the phosphorus mass in Beaver Lake at the beginning of each month, was calculated as the sum of masses in each stratum. The volume of each stratum was calculated from areal measurements of contours on the bathymetric map.

Table VIII-6 reflects monthly values of each variable of the mass-balance equation and the resulting net uptake or release for Beaver Lake.

The mass-balance equation is:

$$P_{int} = (P_2 - P_1) - (P_{in} - P_{out})$$

where:

P_{int} = net phosphorus release (+) or uptake (-) by the sediments
P_1 = in-lake phosphorus mass, beginning of month
P_2 = in-lake phosphorus mass, end of month
P_{in} = phosphorus mass flowing in during the month
P_{out} = phosphorus mass flowing out during the month

Table VIII-5

In-lake Phosphorus Mass

for Beaver Lake

Month	Thermal Layer	TP Conc.	Kg P	Total Monthly P	Month	Thermal Layer	TP Conc.	Kg P	Total Monthly P
Feb 90	Epi	.017	7.4	35.7	Sept 90	Epi	.010	8.8	49.9
	Meta					Meta	.023	13.4	
	Hypo	.013	28.3			Hypo	.024	27.7	
Mar 90	Epi	.018	7.8	40.5	Oct 90	Epi	.008	7.0	65.5
	Meta					Meta	.027	15.8	
	Hypo	.015	32.7			Hypo	.037	42.7	
Apr 90	Epi	.015	6.5	43.6	Nov 90	Epi	.020	8.7	45.7
	Meta					Meta			
	Hypo	.017	37.1			Hypo	.017	37.0	
May 90	Epi	.013	11.4	34.0	Dec 90	Epi	.017	7.4	37.9
	Meta	.015	8.8			Meta			
	Hypo	.012	13.8			Hypo	.014	30.5	
June 90	Epi	.010	8.8	59.4	Jan 91	Epi	.014	6.1	27.9
	Meta	.055	32.2			Meta			
	Hypo	.016	18.5			Hypo	.010	21.8	
July 90	Epi	.010	8.8	48.7	Feb 91	Epi	.014	6.1	27.9
	Meta	.017	9.9			Meta			
	Hypo	.026	30.0			Hypo	.010	21.8	
Aug 90	Epi	.009	7.9	38.0					
	Meta	.012	7.0						
	Hypo	.020	23.1						

Volume $10^3 m^3$

Epilimnion 875.1
Metalimnion 584.7
Hypolimnion 1154.1
Total 2614.0

Volume $10^3 m^3$

1/3 433.5
2/3 2180.5
Total 2614.0

Table VIII-6
Monthly Internal Phosphorus Cycling
Beaver Lake 1990-1991 Gaging Year

Month	P in Subtotal Inflow	P out Total Outflow	P lake 1 (Kg)	P lake 2 (Kg)	P int (Kg)
Feb 90	23.7	18.3	35.7	40.5	-0.6
Mar 90	38.0	22.0	40.5	43.6	-12.6
Apr 90	37.5	26.1	43.6	34.0	-21
May 90	76.5	29.2	34.0	59.4	-21.9
June 90	36.2	9.8	59.4	48.7	-37.1
July 90	23.7	3.2	48.7	38.0	-31.2
Aug 90	49.8	6.4	38.0	49.9	-31.5
Sept 90	13.7	3.1	49.9	65.5	+5.0
Oct 90	93.7	58.0	65.5	45.7	-55.5
Nov 90	53.3	42.5	45.7	37.9	-18.6
Dec 90	37.5	43.9	37.9	27.9	-3.6
Jan 90	58.5	18.7	27.9	27.9	-39.8
					-268.4

P in = monthly subtotal of all P inputs (from P budget)
P out = monthly outflow from outlet (from P budget)
P_1 = monthly P (Kg)
P_2 = next month P (Kg)

Figure VIII-3 demonstrates the capacity of Beaver Lake to assimilate phosphorus. Apparently, Beaver Lake acts as a phosphorus sink, accumulating phosphorus in the sediments for each of the study-year-months except September.

The study year sediment phosphorus uptake was 268 Kg. The minimum monthly uptake occurred in February while maximum phosphorus uptake occurred in October. September was the only month that there was a net sediment release to the water column.

C. Seasonal Phosphorus Contributions To Beaver Lake (1990-1991)

The monthly and total phosphorus budget was derived from the aforementioned components and measured phosphorus concentrations. The following discusses monthly or seasonal phosphorus loading by each of the components to Beaver Lake.

Budget components and phosphorus data were derived for the months February, 1990 through January, 1991. Monthly phosphorus loading to Beaver Lake by the major inflowing tributaries is presented in Figure VIII-4. In a normal hydrologic year, much of the monthly phosphorus loading occurs from late February to early April when winter snowmelt erodes subwatershed material and strips phosphorus which has accumulated since fall. However, the combination of a below normal winter snowfall and an above normal fall rainfall lead to only a moderate spring runoff and an extensive fall runoff. August of 1990 was noted for significant rainfall from both high intensity, short duration storms and low intensity long duration storms. August's rainfall accounted for 25 percent of the total study year rainfall while the three months of January, February and March represented 12 percent of the study year budget. The tributary phosphorus budget contribution from August is underestimated, due to the difficult to gage high intensity, short duration rain events which occurred.

Monthly external phosphorus loading trends, exclusive of tributary loading, are presented in Figure VIII-5. Atmospheric contribution depends upon the amount of precipitation that occurs over a given period of time. Atmospheric contribution and runoff loading during the winter months is often low because precipitation is usually in the form of snow, and runoff is slight. As the phosphorus budget reveals (Table VIII-7), 25 percent of the atmospheric load to Beaver Lake occurred during the heavy rainfall month of August, 1990. Direct runoff is dependent upon precipitation and soil conditions. Generally, the spring melting of the winter snowpack in

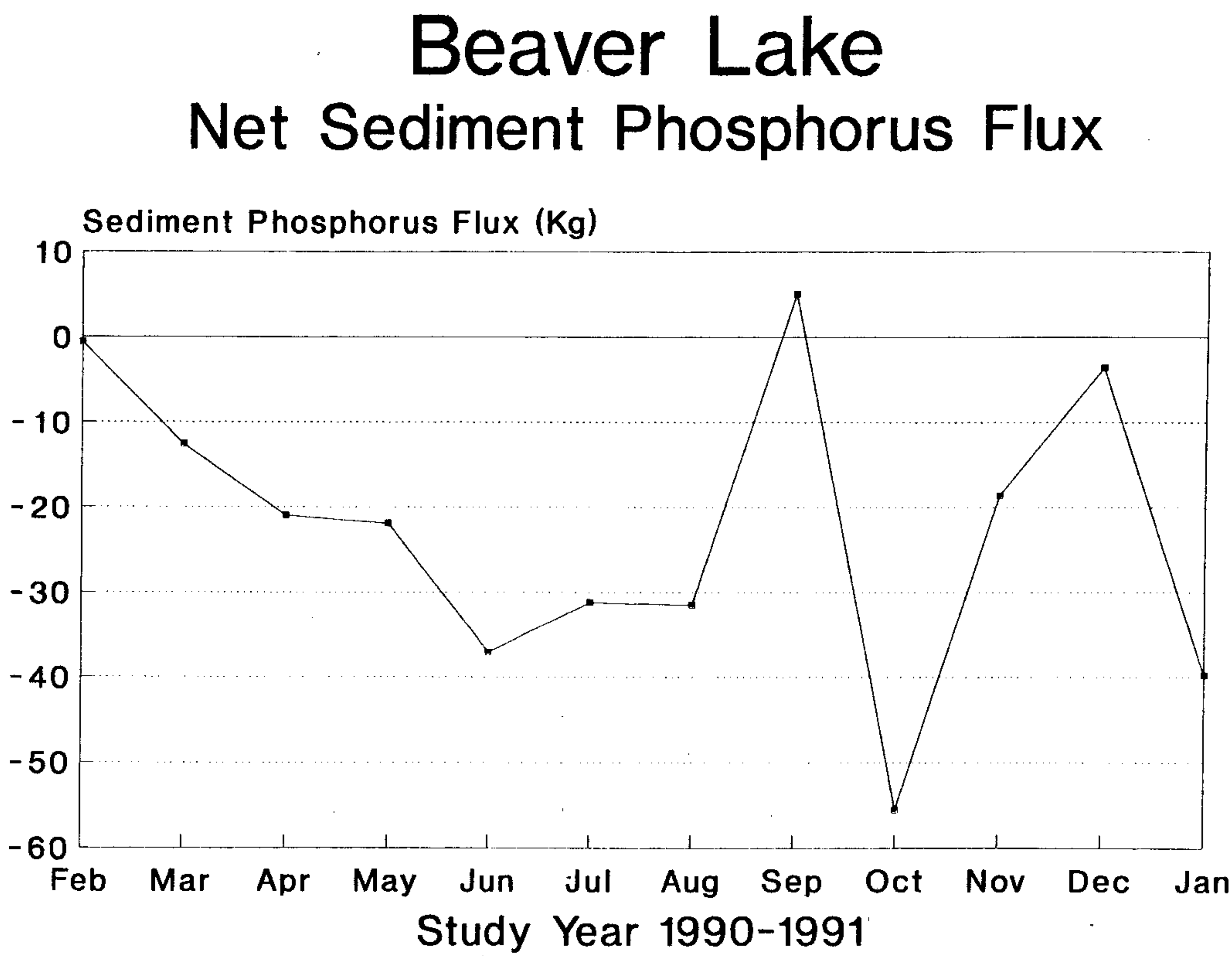


Figure VIII-3. Capacity to Assimilate Phosphorus

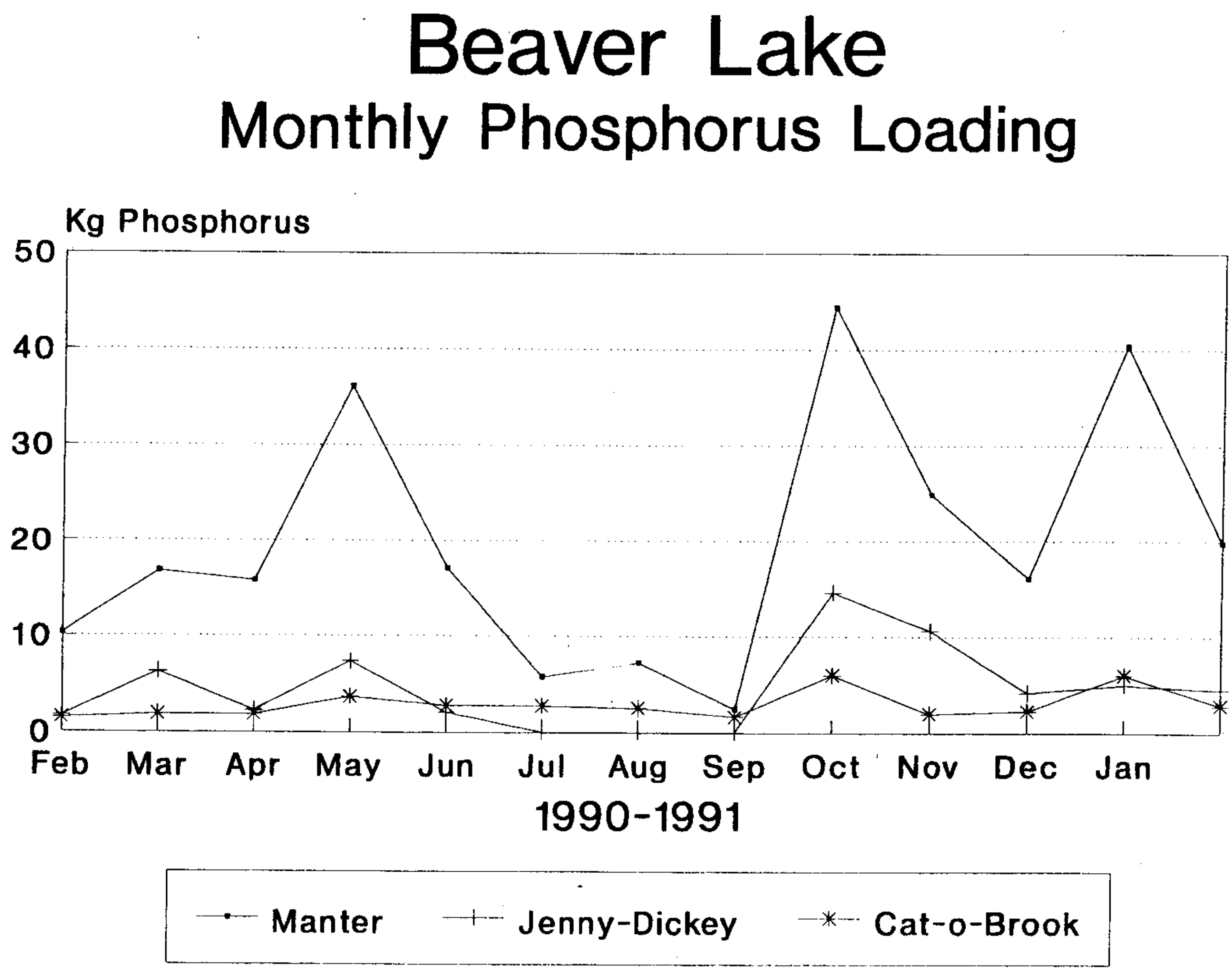


Figure VIII-4. Monthly Phosphorus Load to Beaver Lake by the Major Inflowing Tributaries

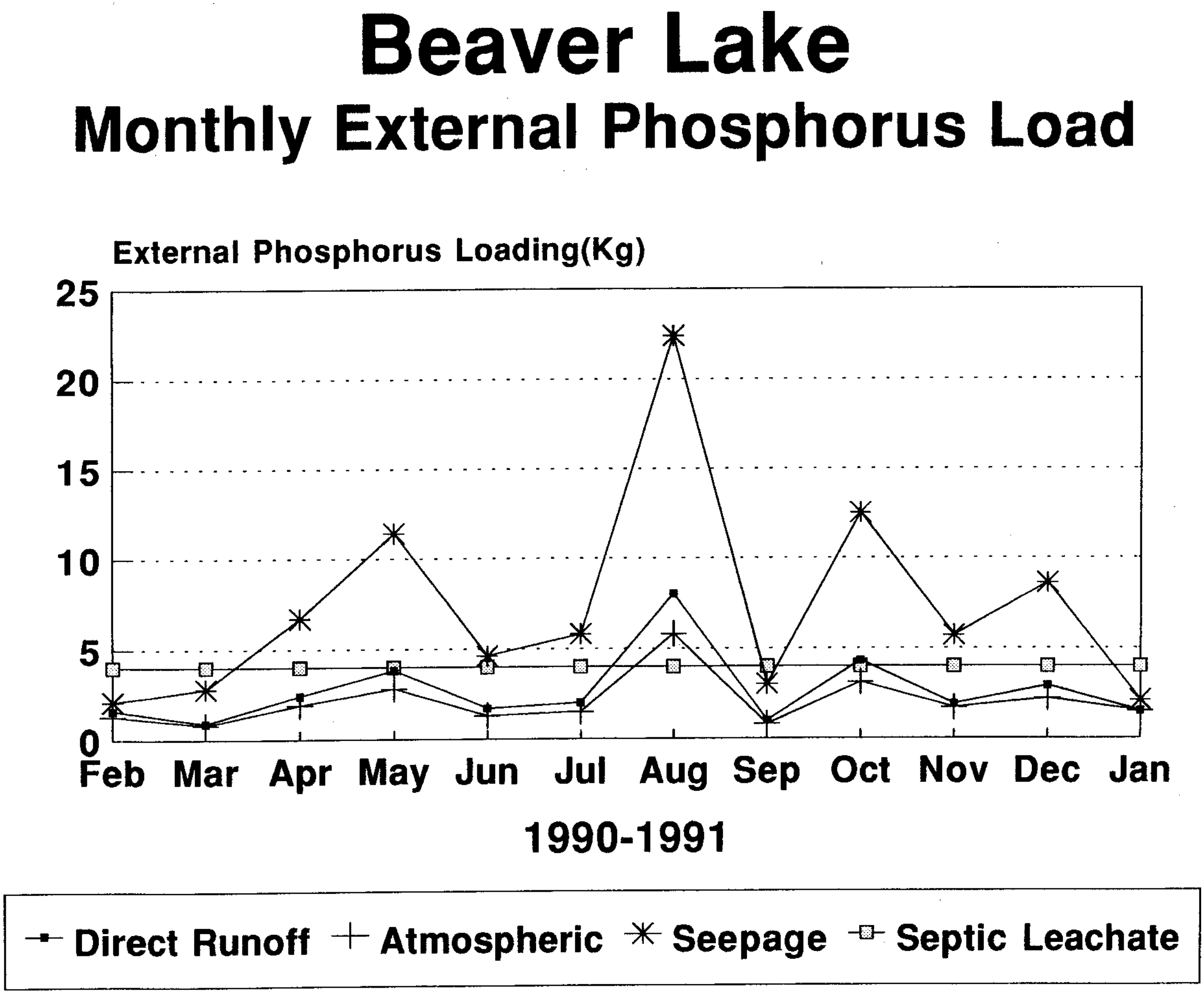


Figure VIII-5. Monthly External Phosphorus Load (Exclusive of Tributaries)

Table VIII-7
Beaver Lake Phosphorus Budget for Gaging Period (Phosphorus Loading in Kg)

Component	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Mean Monthly	Total Annual
Qi_1	10.3	16.8	15.8	36.1	17.1	5.8	7.3	2.5	44.4	24.9	16.1	40.4	19.8	237.5
Qi_2	1.7	6.3	2.3	7.4	2.1	<0.1	0.1	0.1	14.6	10.6	4.2	5.0	4.5	54.4
Qi_3	1.5	1.9	1.9	3.7	2.8	2.8	2.6	1.7	6.0	2.0	2.3	6.0	2.9	35.2
Qi_4	4.1	0.5	0.8	0.5	0.2	<0.1	<0.1	<0.1	1.5	0.4	0.2	0.2	0.7	8.4
Qi_5	0.3	0.8	0.5	2.4	0.2	0.1	<0.1	0.2	0.3	1.7	0.3	0.6	0.6	7.4
Qi_6	0.1	0.6	0.2	0.2	0.1	<0.1	<0.1	<0.1	0.4	0.2	0.1	0.7	0.2	2.6
Qi_7	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.5	0.2	0.2	1.2	0.2	2.2
Qi_8	0.4	0.3	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1	0.1	0.1	1.1
Qi_9	<0.1	<0.1	0.2	0.3	0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1	0.1	0.8
R Direct Runoff	1.6	0.9	2.4	3.8	1.7	2.0	8.0	1.0	4.3	1.9	2.9	1.5	2.7	32.0
P lake Atmos-pheric	1.3	0.8	1.9	2.8	1.3	1.5	5.8	0.8	3.1	1.7	2.1	1.5	2.1	24.0

Table VIII-7
Beaver Lake Phosphorus Budget for Gaging Period (Phosphorus Loading in Kg)
(contd.)

Component	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Monthly	Annual
QW_i GW seepage	2.1	2.8	6.7	11.4	4.6	5.8	22.4	3.0	12.5	5.7	8.6	2.1	7.3	87.7
Septic Leachate	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	48.0
Sub-total	27.4	35.7	36.7	72.7	34.2	22.1	50.2	13.3	91.7	53.4	41.2	63.4	45.2	541.3
Net sediment release(+) uptake(-)	-0.6	-12.6	-21.0	-21.9	-37.1	-31.2	-31.5	+5.0	-55.5	-18.6	-3.6	-39.8	-22.4	-268.4
Total Influx	26.8	23.1	15.7	50.8	-2.9	-9.1	18.7	18.3	36.2	34.8	37.6	23.6	24.7	296.4
Qo_1	14.8	17.6	21.3	24.1	9.3	2.8	5.7	2.7	48.3	35.8	38.6	15.5	19.7	236.5
Qo_2	3.5	4.4	4.9	5.1	0.5	0.4	0.7	0.4	9.7	6.7	5.3	3.2	3.7	44.9
Total Outflow	18.3	22.0	26.2	29.2	9.8	3.2	6.4	3.1	58.0	42.5	43.9	18.7	23.5	281.4

Q_i1 - Manter Brook
Q_i2 - Jenny-Dickey Brook
Q_i3 - Cat-O-Brook
Q_i4 - Cat-O-Swamp
Q_i5 - Comeau's Brook
Q_i6 - Rte. 102 Inlet
Q_i7 - Development Brook
Q_i8 - B.L.A.C. Tributary
Q_i9 - Clark Brook

combination with semi-impermeable frozen soils lead to high direct phosphorus runoff. High intensity rain events also increase direct runoff of phosphorus as little of the fallen precipitation has the opportunity to percolate through the soils. Low intensity storm events usually produce little direct runoff phosphorus as much of the water is absorbed into the usually dry summer soils.

Seasonally, little direct runoff was calculated for the winter months for Beaver Lake. Direct phosphorus runoff increased during April and May, decreased in June and July but dramatically increased in August when rainfall increased. Direct runoff was lower during September and November but above the mean during October.

Groundwater seepage loading of phosphorus to the lake also followed seasonal patterns. An increase in water table forces more water and phosphorus into the lake. In the same manner, an increase in septic system usage will increase the quantity of water in the saturated lake shoreland water table, and increase the nutrient loading to the groundwater.

Beaver Lake received much of its groundwater phosphorus during the late spring, when the ground thawed, during the late wet summer months, and in October.

Septic export of phosphorus remained fairly constant during the study year. Since this area is now sewered, a more even distribution of phosphorus is expected.

Septic leachate would have been the second greatest phosphorus contributor representing 28 percent of the phosphorus budget if sewering had not been accomplished. Sewering is estimated to have reduced the phosphorus load from leachfields to the lake from 190 Kg P/yr to 48 Kg P/yr or by 142 Kg P yr. This represents a 75 percent reduction of phosphorus from the lake attributed to sewering. Once the phosphorus forms in the old saturated leachfields finally reach the groundwater and are utilized by the lake biota, a total phosphorus reduction of 28 percent may eventually by achieved.

Septic leachate loading to Beaver Lake prior to sewering was 43% higher than three recently completed diagnostic/feasibility studies: Mendums Pond, Barrington at 19 percent (Connor, McCarthy and O'Loan, 1992). Webster Lake, Franklin at 16 percent (Connor and Dubis, 1990) and French Pond, Henniker at almost 20 percent (Connor and Martin, 1988). However, the sewered shoreline contribution was less than those previously studied (9%).

Figure VIII-6 presents total monthly external loading over the 1990-1991 study period. Maximum loading was achieved during October and May of 1990. These two months yielded 31 percent of the annual phosphorus load to Beaver Lake. The above average rainfall, higher water table, and increased watershed runoff all contributed to the maximum phosphorus load to Beaver Lake.

In a normalized sample year, a combination of high volumes of watershed snowmelt water and the meltwater capacity to carry phosphorus-laden particulates are the contributing factors to loadings in February and March or March and April. However, only 14 percent of the annual phosphorus load was delivered to Beaver Lake during March and April of the study period.

D. Annual Phosphorus Budget for Beaver Lake (1990-1991)

The total phosphorus budget as a whole and the percent contribution of each component to Beaver Lake is one of the most important products of this study.

A pie diagram (Figure VIII-7) shows the external phosphorus contribution to Beaver Lake as percent of the total budget, while Table VIII-7 presents the 1990-1991 gaging year phosphorus budget for Beaver Lake.

The combination of all nine inflowing tributaries to Beaver Lake accounted for 65 percent of the phosphorus budget. The combination of three brooks, Manter Brook (238 Kg,) Jenny-Dickey Brook (54 Kg), and Cat-O-Brook (35 Kg), represented 93 percent of the tributary phosphorus load to the lake. When compared to other studies, the tributary phosphorus loading was higher than that to French Pond (Connor and Martin, 1988) but was lower than tributary loading measured at Kezar Lake, which contributed 73 percent of the phosphorus flux (Connor and Smith, 1983) and Northwood Lake which accounted for 83 percent of the phosphorus budget (Estabrook and Towne, 1982).

With the phosphorus reduction to the lake by sewering, groundwater seepage becomes the second greatest contributor of phosphorus to Beaver Lake. Groundwater seepage contributed 88 Kg P/yr and represented 16 percent of the study year budget. The phosphorus seepage contribution is higher than what most New Hampshire studies have shown. Seepage phosphorus contributions generally range from five to ten percent of the phosphorus budget.

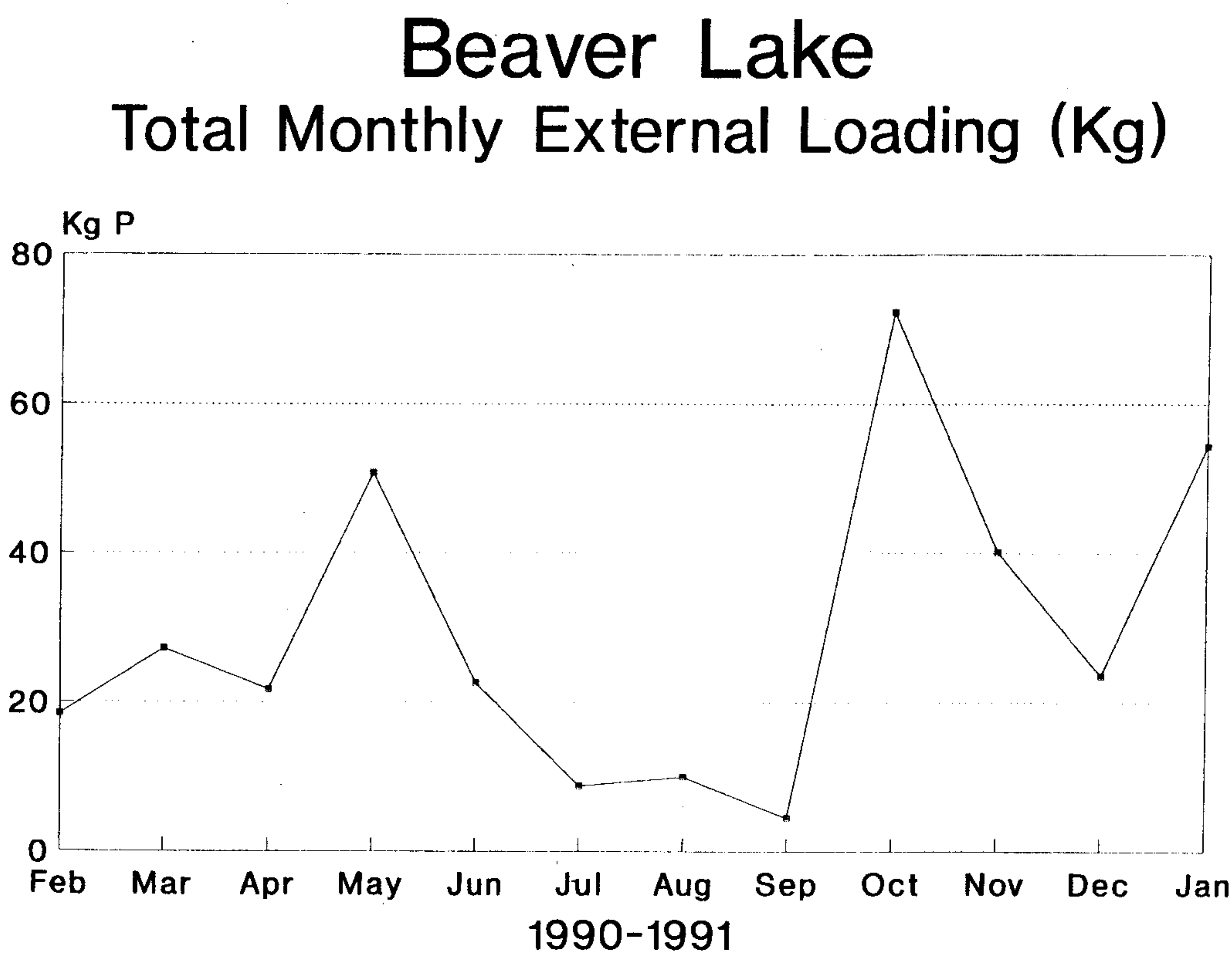


Figure VIII-6. Total Monthly External Loading

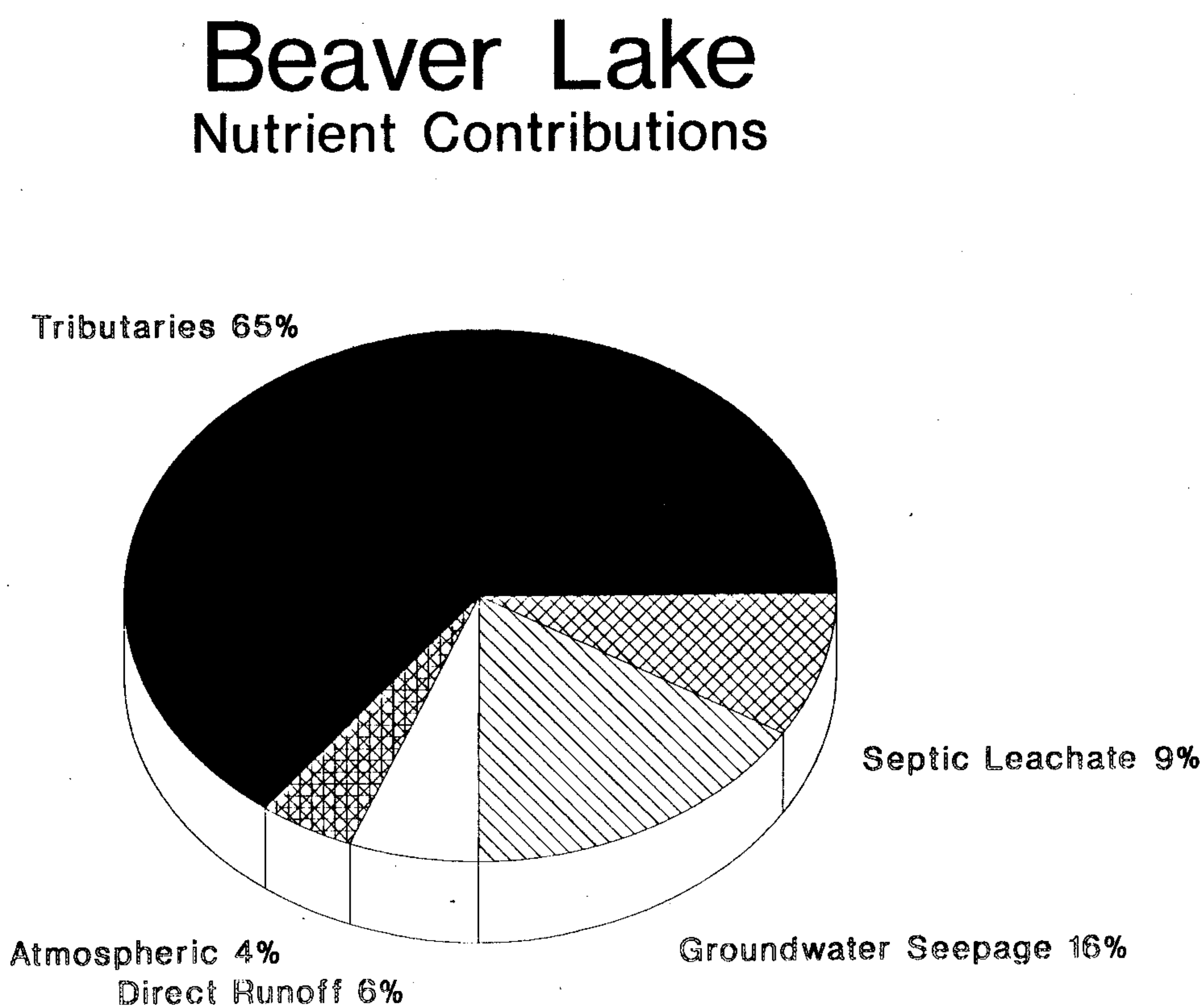


Figure VIII-7. External Phosphorus Contribution to Beaver Lake

Direct watershed phosphorus runoff into the pond contributed 32 Kg or six percent of the total phosphorus load to Beaver Lake.

Atmospheric deposition delivered 25 Kg of wetfall and dryfall phosphorus to Beaver Lake during the 1990-1991 study year.

Oxygen deficiencies were measured in the hypolimnion of Beaver Lake for 42 percent of the study year. Hypolimnetic anoxia is highly conducive to the release of phosphorus from the sediment and interstitial water to the immediate water column. Increases of hypolimnetic phosphorus in Beaver Lake coincided with low hypolimnetic dissolved oxygen during July, August and early September. Hypolimnetic phosphorus and dissolved oxygen data reveal that there is currently a problem with internal phosphorus loading.

Although the Beaver Lake phosphorus budget shows a net uptake of phosphorus, it must be emphasized that sediment release and uptake are simultaneously occurring functions in different sections of the lake, and that other chemical, physical and biological activities are also occurring. While one section of the lake may be releasing phosphorus for some of the year, other areas of the lake are uptaking phosphorus. As discussed previously in the sediment release section, only one month showed a net release of phosphorus to the water column. Hypolimnetic phosphorus data collected during the 1990 summer study period confirmed that internal phosphorus loading is a problem in Beaver Lake. A comparison between epilimnetic phosphorus (range = 6-13 ug/L) and hypolimnetic phosphorus (range = 12-37 ug/L) shows that hypolimnetic phosphorus is two to three times greater than epilimnetic phosphorus over the same period of time.

The study year phosphorus budget reflects a subtotal annual phosphorus influx of 542 Kg. The estimated net sediment uptake was 268 Kg. The total influx to the lake after sediment uptake was 296 Kg, in which 281 Kg left the lake through the two outlets.

1. Storm Event Phosphorus Loading to Beaver Lake

Storm events can be a significant factor in calculating a phosphorus budget. However, they are one of the most difficult parts of the budget to quantitate. Accumulating storm event data can be costly; equipment to sample and record flows must be purchased and operated. Nonetheless, the expense is justified if an accurate phosphorus budget is to be developed. Dennis, (1986), estimated that the four largest runoff events accounted for 65 percent of the total phosphorus export to a Maine Lake, and a single storm event contributed almost 50 percent of the phosphorus load to that same lake.

Many studies have shown that much of the phosphorus load can occur during the first centimeter of rainfall. A study conducted in a Maine watershed estimates that 69 percent of the phosphorus export occurred during the first centimeter of runoff while 90 percent and 97 percent occurs during the first two cm and three cm respectively.

The rain event sampled occured during August of 1991 with the onset of Hurricane Bob. The area received over 3.82 inches of rainfall during an estimated 8 hour event. The storm event occurred after the gaged year of the phosphorus budget. During the 12 month study period the tributaries contributed 349 Kg of phosphorus to the lake, yet during the storm event an estimated 213 Kg were deposited. If the storm occurred during the gaged year this one event would have resulted in 61% of the total tributary loading to Beaver Lake. All of the storm event discharge data are presented in Appendix VI-2. The hydrologic component of the storm event is presented in Chapter VII. The storm event peak flow times and discharge for each station are presented in Table VII-5 and Figure VIII-8. Storm event total phosphorus data is presented in Figure VIII-9.

The storm event phosphorus loading data, which includes discharge, phosphorus concentration and phosphorus export at time of sampling is presented here. Phosphorus concentrations varied from station to station and over time. Figure VIII-10 lists phosphorus loadings for each station at each interval sampled. For the majority of the tributaries, maximum loading occurred during and after interval seven, approximately four and a half hours after the storm began. The B.L.A.C. tributary had its maximum TP load during interval six. This is most probably due to the small watershed of the tributary. A small watershed will reach maximum capacity for holding water sooner than a large watershed, therefore the excess nutrients get "flushed" more quickly. Development Brook and Cat-O-Brook had maximum loadings during interval seven. Development Brook, like the B.L.A.C. tributary, has a small watershed. However, the existence of a small retention pond adjacent to the lake probably slowed the discharge.

The Cat-O-Brook and Cat-O-Swamp tributary data must be interpreted carefully. At approximately 3:15 pm the water levels had risen to such an

Storm Event Peak Flow Discharge

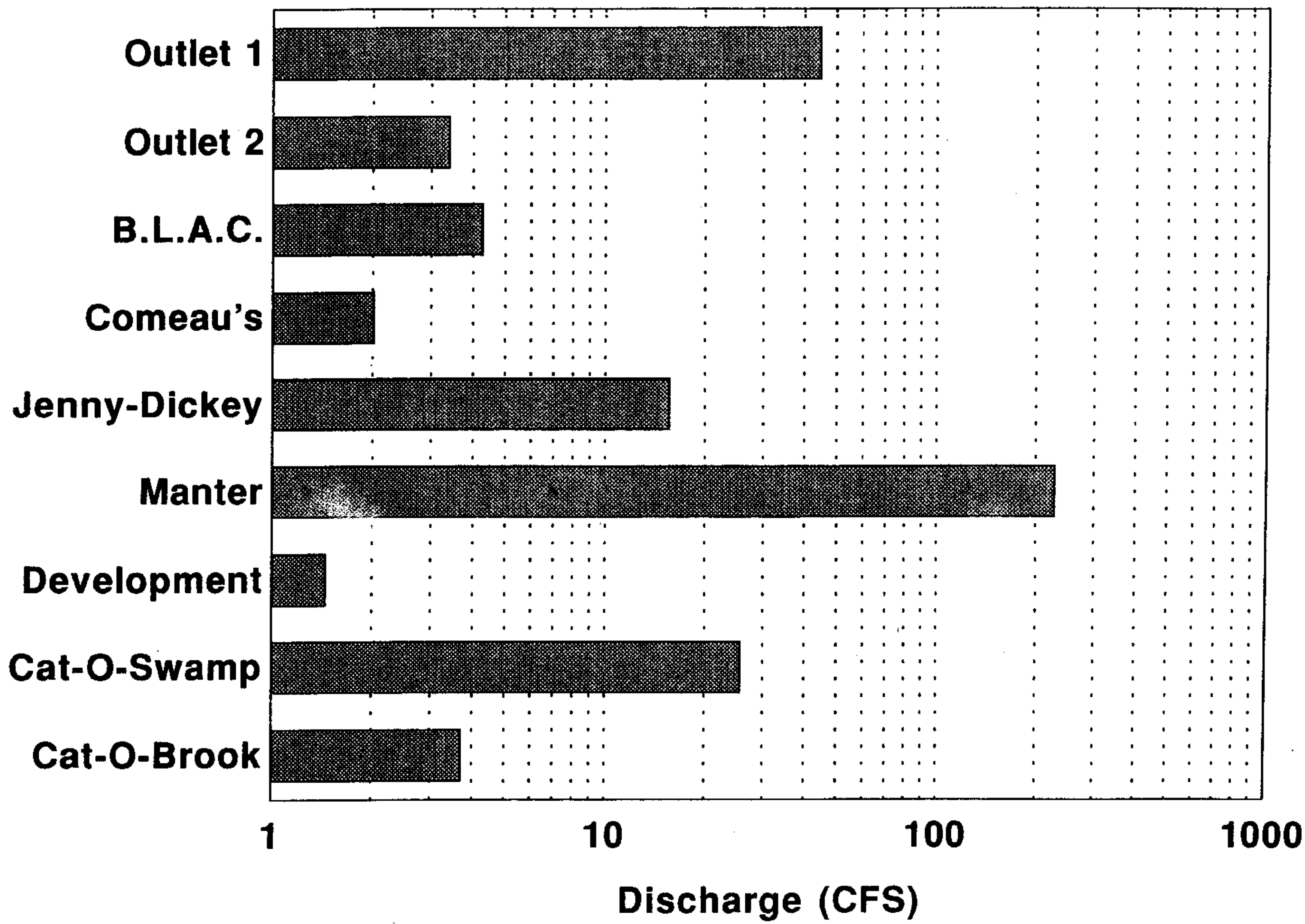


Figure VIII-8. Storm Event Peak Flow Discharge

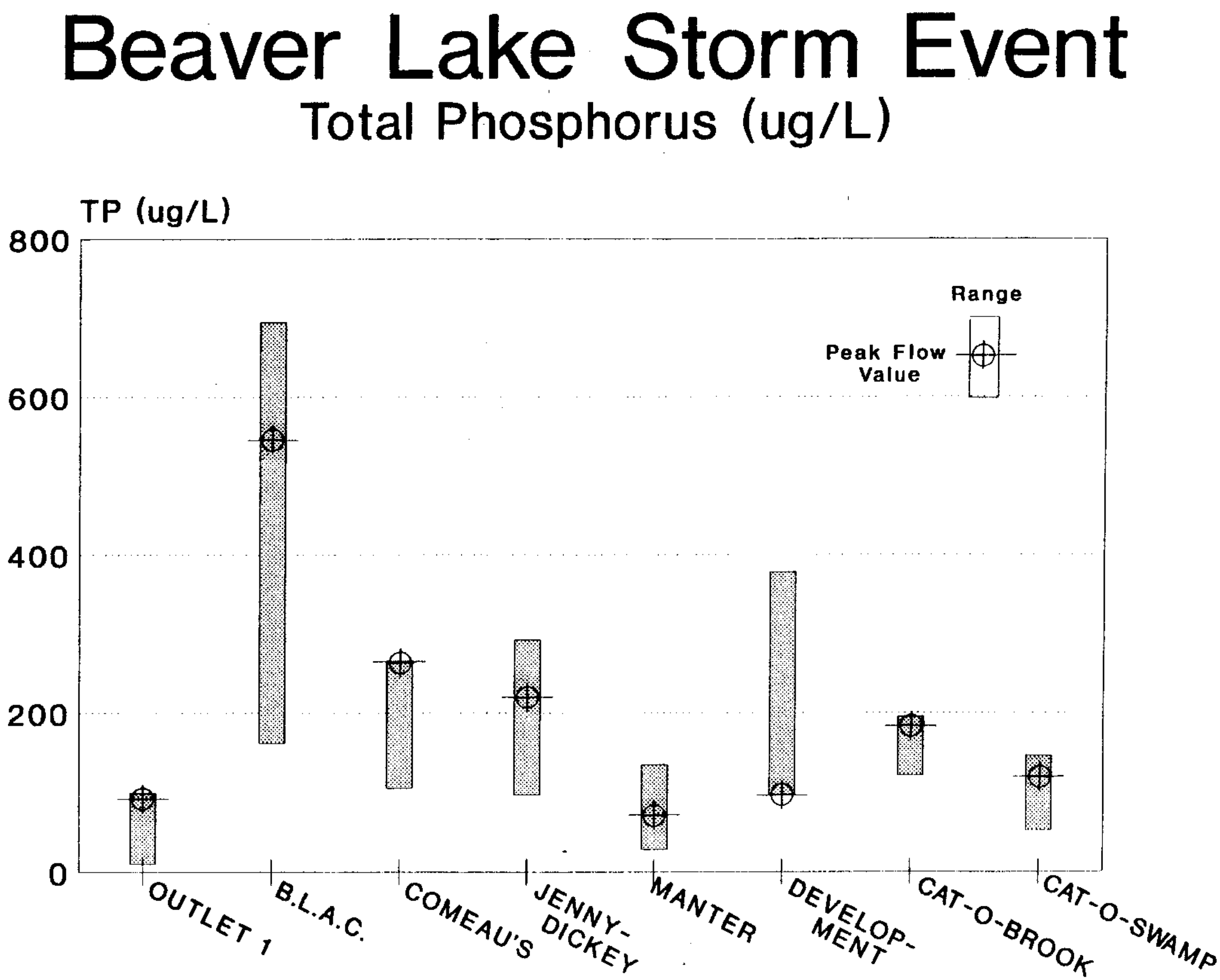
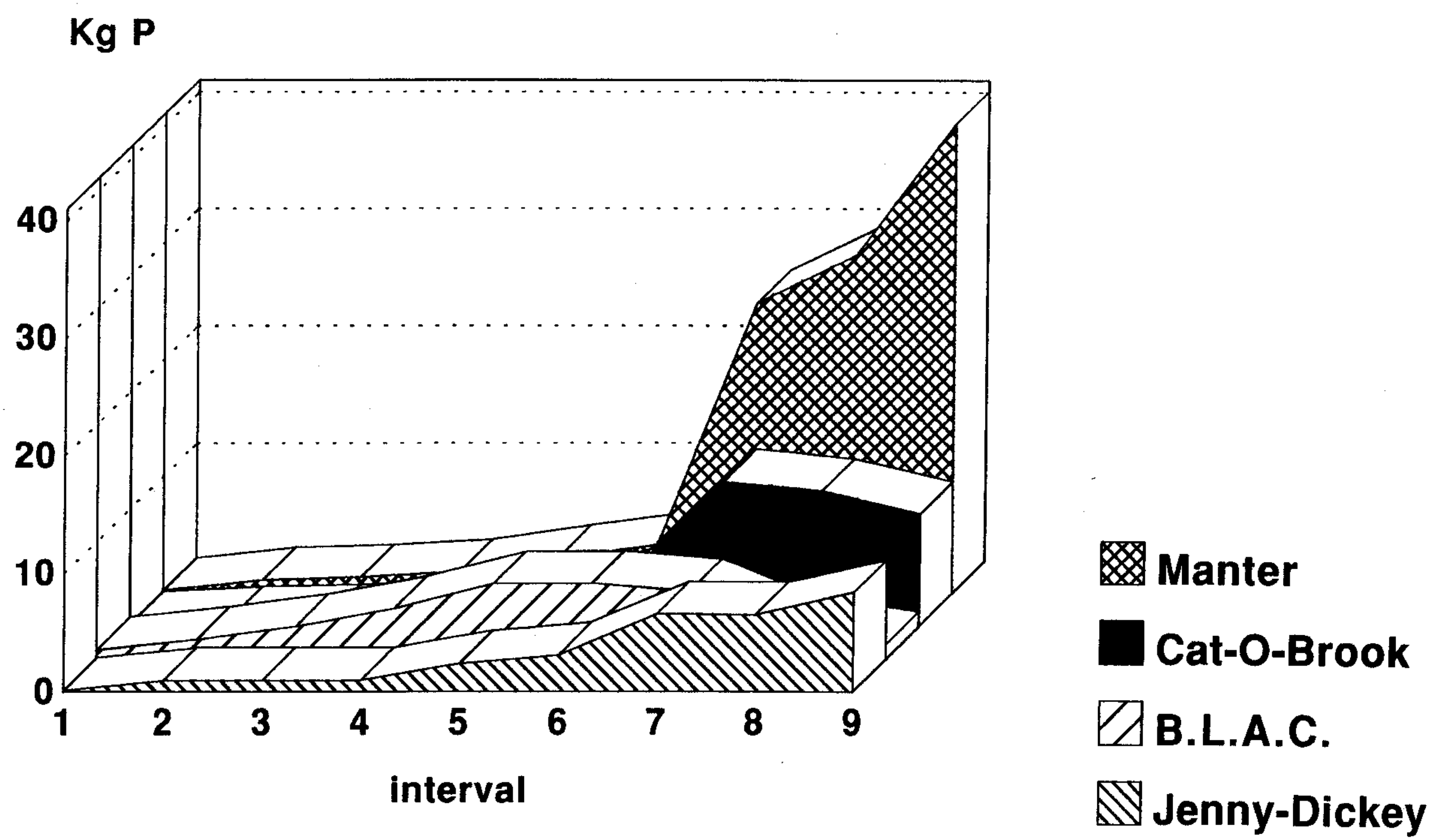


Figure VIII-9. Beaver Lake Storm Event Total Phosphorus

Beaver Lake Storm Event

Phosphorus Loading Kg P



note:scales are different

Figure VIII-10. Beaver Lake Storm Event Phosphorus Loading

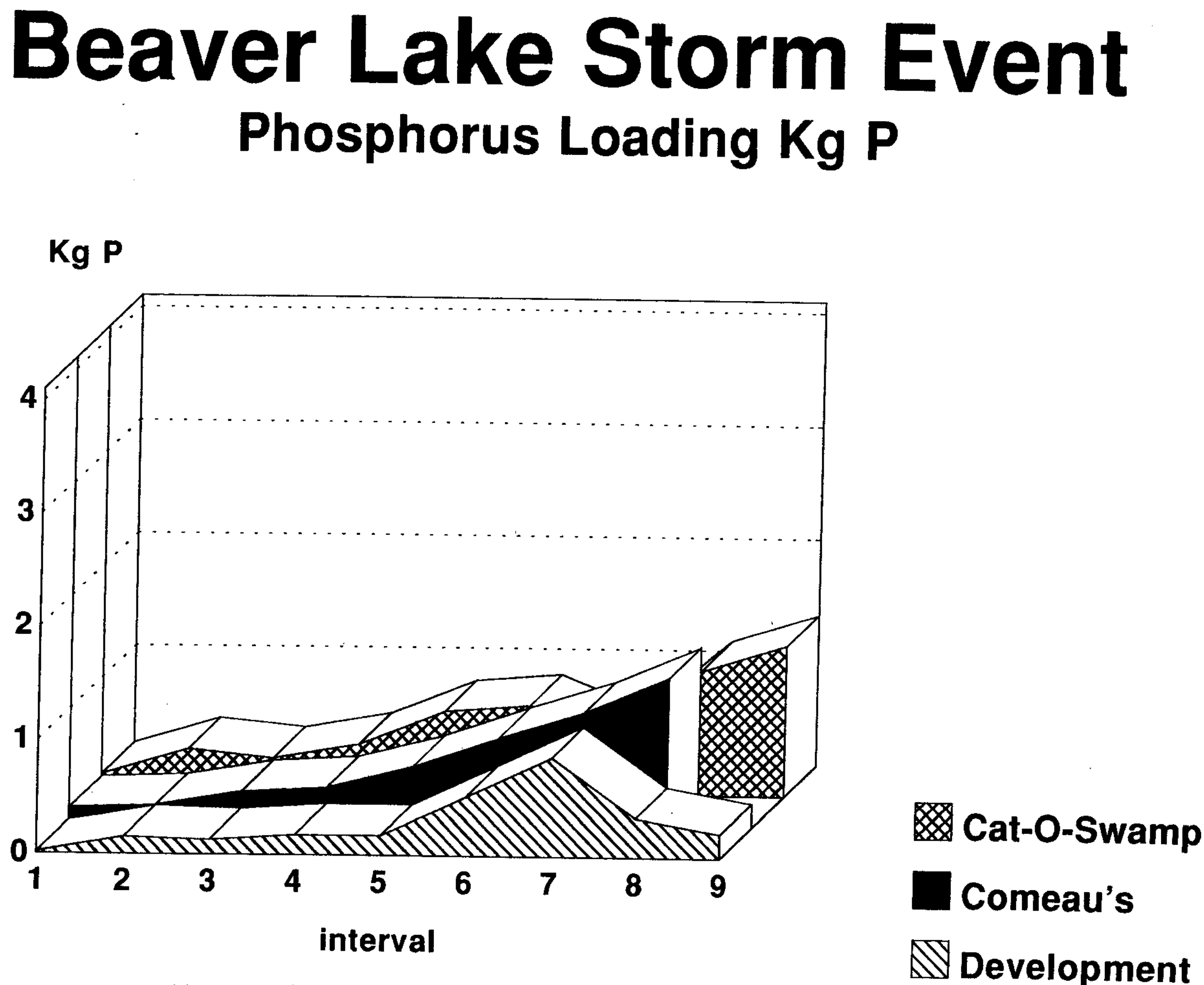


Figure VIII-10. Beaver Lake Storm Event Phosphorus Loading (cont.)

extent that the staff gages were completely submerged. This situation made it difficult for estimation of both discharge and phosphorus loading. For intervals seven, eight and nine the highest staff gage number was used for calculations, but it must be kept in mind that these numbers are below the "real" values. Therefore, it is impossible to estimate both peak discharge and peak loading times for these tributaries.

The sampling of Comeau's Beach Brook also presented some problems. The last interval sampled, at 4:30 pm was the highest for TP loading. Interval 9 was not sampled because of a fallen powerline in the tributary vicinity, but it is probable that the peak had not yet occurred.

The remaining tributaries showed peak loading times during the last interval sampled. It is most likely that the phosphorus flush declined from this point on, as the rain had abated.

Total tributary phosphorus load is presented in Figure VIII-11. The greatest contributor for the five and a half hour event was Manter Brook, which released approximately 105 Kg of phosphorus into the lake. This accounted for 47.8% of phosphorus discharged during the storm event. Manter Brook contributed the greatest water volume discharge into the lake during the storm event.

The second highest contributor of phosphorus was Cat-O-Brook tributary, which released approximately 41 Kg of phosphorus (18.8% of the total load). These numbers are an underestimation of total load, due to factors mentioned previously.

The next highest contributors were the B.L.A.C. tributary and Jenney-Dickey Brook which added approximately 31 and 30 Kg respectively (14.2% and 13.5%). The remaining three brooks each added under 6 Kg of phosphorus to the budget, and collectively contributed only 5.7% of the storm event loading.

Beaver Lake Storm Event
Total Loading Kg P

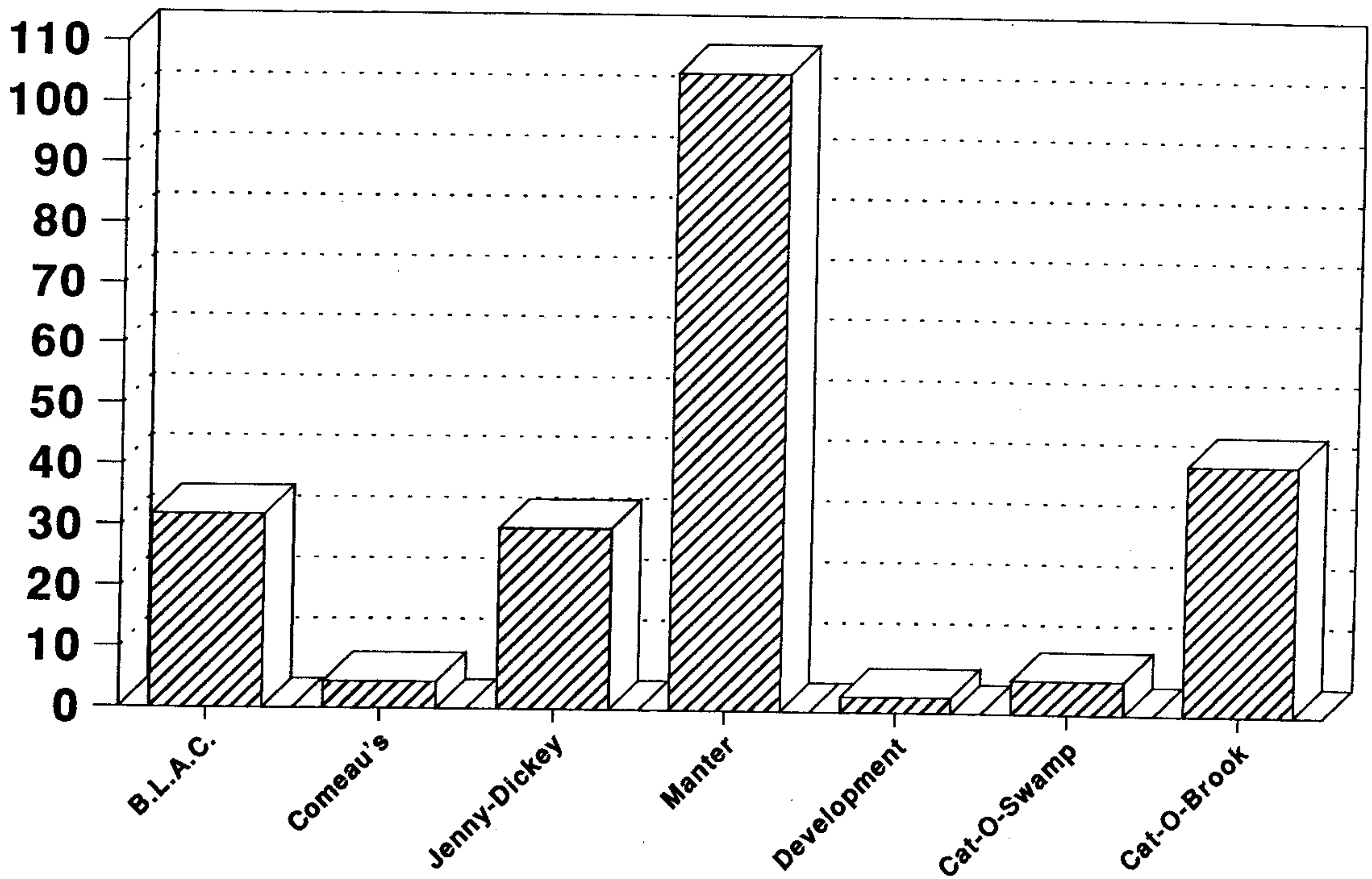


Figure VIII-11. Beaver Lake Storm Event Total Loading

IX. BOTTOM SEDIMENT COMPOSITION

A. Introduction

Lake sediments have proven to be of extreme importance to limnologists because they play an important role in the determination of nutrient levels buffering and productivity in the overlying waters.

A review of the factors that may affect sediment-water exchange reactions shows that insufficient information is available at the present time to predict the extent and, in many cases, the net direction of exchange for many compounds in most natural waters. Lake sediments contain significant concentrations of many metals and nutrients. The lake sediments act as a buffer system for these elements to control concentrations in the overlying waters. The effect of this buffer system could be to keep the concentrations in the overlying waters relatively constant even though the concentrations of the element in the inflowing waters vary greatly (Lee, 1970).

One of the most important reactions of this type is the exchange of phosphorus between a lake's sediments and the overlying waters as related to the eutrophication of the waters. Lee (1970) states that lake sediments typically contain one to two parts per thousand of phosphorus per kilogram of dry sediment.

Knowledge is particularly lacking on the role of lake sediments in maintaining phosphorus levels in water. It is not known if the sediments of a lake act as a sink in which the majority of the phosphorus present is refractory, i.e., not available for exchange reactions, or as a source, contributing phosphorus to the lake to sustain plant growth.

Frink (1967) suggests that the center of a lake acts as a reservoir for both total and available nitrogen and phosphorus. He concludes that nutrients which accumulate in the bottom of a lake as eutrophication proceeds constitute a vast reservoir apparently capable of supporting plant growth in the event nutrient input is reduced. This was the case at Kezar Lake, North Sutton, New Hampshire. Even after phosphorus loading was dramatically reduced from a point source, phytoplankton blooms continued on an annual basis. Phosphorus rich sediments continued releasing phosphorus into the upper water column supporting a vast population of phytoplankton (Connor and Smith, 1983).

In addition to phosphorus, metal concentrations in the sediment can play a role in the ecological health of a lake. With the increasing concern of acidic precipitation in New Hampshire, lake or pond pH and A.N.C. have become increasingly important to the lake's health. Studies have shown various mechanisms of response of the lake's biota to increased acidity, ranging from the direct toxicity of the elevated hydrogen ion concentration to disruptions of normal food-chain relations and behavioral patterns of animals. Biogeochemical cycles in the lake may also be affected and, in turn, disrupt the biota. Recent studies have shown increasing concentrations of heavy metals such as manganese, aluminum and zinc as a result of pH depressions below five units.

B. Chemical Characterization

A Wildco KB^{tm} coring device was utilized to extract a 13 inch sediment core. The core was collected at the deepest location of Beaver Lake and sectioned off into one inch upper, two inch middle and three to four inch bottom sediment column intervals. Metals were digested using a CEM Model 81 microwave digestion unit and run on an inductively coupled plasma atomic emission spectrometer. Sediment phosphorus concentrations were determined colormetrically after digestion. Such measurements could reflect deposition rates, toxic metal concentrations, phosphorus sediment accumulation, and spatial variability over time.

When assessing spatial variability over time one must use caution. Iskandar and Keeney (1974) stated that concentration distribution of any element in a sediment profile must be treated cautiously due to mixing of the sediments. This is reiterated by Lee (1970) who stated that at least partial mixing of the sediments occurs for 5-20 cm below the sediment surface. This mixing occurs due to both natural processes and man-induced conditions. Natural mixing processes include thermal gradients, wind pressure and waves, organism mobility (i.e. insect larvae and worms) and the formation of gas bubbles and pockets. Man-made mixing occurs due to recreational activities (i.e. boating) or artificial mixing of the lake. In addition to mixing, some elements can diffuse upward due to differing gradients in the overlying water (Yousef, et al., 1979). For this reason we focus more on the general trends of concentrations than the segment to segment variances. Comparison of other lake sediment core analyses performed in New Hampshire are presented in Table IX-1. A summary table of sediment analyses appears in Table IX-2.

Table IX-1
Comparison of Surface Sediments (first inch) of
some of New Hampshire Lakes and Ponds.

Parameter/lake	Classification	Al	Cd	Cu	Fe	Pb	Zn	Tp
Beaver Lake Derry	Eutrophic	23,760	5	26	26,760	139	227	2,359
Mendums Pond Barrington	Oligotrophic	16,800	<4	<80	13,120	101	80	7,128
*Webster Lake Franklin	Mesotrophic	20,500	1	17	26,000	94	140	4,735
Mtn. Pond Chatham	Oligotrophic	25,120	<24	<80	16,320	98	184	4,530
Loon Lake Plymouth	Mesotrophic	14,921	<24	<80	30,595	48	159	7,211
Kezar Lake Sutton	Eutrophic	23,585	<236	830	16,038	58	6,604	5,569
French's Pond Henniker	Eutrophic	16,812	<30	69	27,525	723	317	10,165

All values in mg/kg dry weight of sediment
*Method utilizing CEM microwave (except Mn and Tp)

Table IX-2

Recoverable Metals from Beaver Lake Sediments (mg/kg)

Sediment Section (inches)	Dry Wt (gms)	Al	Cd	Cr	Cu	Fe	Pb	Zn	P	Ca	Mg	K	Na
0-1"	1.000	23,760	4.7	60.9	25.9	26,760	139.2	226.7	1,769	4,586	5,310	2,316	297.3
1"-2"	1.002	26,018	4.8	65.3	28.2	26,806	158.8	251.5	1,967	5,399	5,708	2,286	295.6
2"-3"	1.002	25,499	4.8	65.3	28.6	25,658	166.4	258.1	1,765	5,319	5,678	2,080	273.0
3"-5"	1.005	24,696	4.5	63.5	27.2	23,920	186.1	250.2	1,620	4,972	5,472	1,888	277.1
5"-7"	1.002	25,129	4.7	66.3	27.1	24,281	188.6	251.1	1,596	4,737	5,788	1,832	241.0
7"-10"	1.000	24,250	4.1	65.7	24.5	21,710	159.7	230.8	1,368	4,348	5,950	1,671	213.5
10"-13"	1.001	22,927	3.0	60.0	16.2	19,880	75.7	128.7	1,370	4,068	5,824	1,610	200.2

C. Sedimentation Rates and Sediment Age

The relative age of the sediments of Beaver Lake were estimated using lead concentrations as an indicator. Figure IX-5 depicts the increase in lead concentration at the 6 inch level. This increase corresponds to the introduction and increased use of leaded gasoline during the 1920's.

Utilizing this date and assuming the surface corresponds to 1990 when the core was removed, relative sedimentation rates can be estimated at .086 inches (2.13 mm) year^{-1} from the six inch to the surface layer.

These values correspond to values from other lakes that do not have point source discharges. The Connecticut Department of Environmental Protection estimated that 2.0 feet (0.61m) of sediment had been deposited in eutrophic Lake Lillionah between 1955 and 1980. This equals a sediment deposition rate of approximately 1 in. (2.5 cm) yr^{-1}. Sedimentation in Lake Lillionah is unusually high, as compared to most Connecticut lakes, in that Lillionah experiences dense summer blooms of blue-green algae and received indirect discharge of treated wastewater from an upstream sewage treatment plant. Peterson, et al. (1973) discusses sedimentation rates for Lake Trummen, located in Sweden. Approximately 40 cm of FeS-colored (black) fine sediment was deposited over a period of 25 years, or at a rate of about 0.6 in. (1.6 cm) yr^{-1}. Lake Trummen was also subject to the discharge of wastewater effluent for many years, and the significance of internal nutrient recycling was well documented. At mesotrophic Stockbridge Bowl, located in Stockbridge, Massachusetts, Ludium (1975) reported a much lower sedimentation rate of 0.12 inches (3.0-3.2 mm) year^{-1}. The Maine Department of Environmental Protection assumes an approximate sedimentation rate of 0.08 inches (2.0 mm) year^{-1} (Maine DEP, personal communication).

D. Sediment Metals and Phosphorus

Values presented in the following discussion are for concentrations which were measured in the sediment and not in the water. Elevated metal concentrations would not be expected to be measured in lake water unless low pH values (below 5.0 units) were commonly measured within the lake.

1. Recoverable Aluminum

One of the most abundant elements on the face of the earth, aluminum occurs in many rocks but never as pure metal in nature. Although the metal itself is insoluble, many of its salts are readily soluble.

The toxicity of aluminum to the aquatic biota has been reviewed quite extensively with the recent association of resolublization of aluminum in acidic waters. Aluminum toxicity does not appear to be a significant problem, as long as pH is controlled and residual dissolved aluminum is not allowed to reach levels in the area of 50 ug Al/L. In areas where lakes have low ANC and acid rainfall is significant, lowering of lake pH could occur with a sudden increase in aluminum and probable toxic affects to the lake biota.

Aluminum concentrations in Beaver Lake (Table IX-2, Figure IX-1) sediments exhibited a range of values. The maximum concentration observed was 26,018 mg/kg (1-2 inch segment), while the minimum was 22,927 mg/kg (10-13 inch segment). Aluminum concentrations show a general rise from the bottom part of the sediment core to the one inch segment. The surface sediments show a decline in concentration. Possible explanations for the elevation of aluminum concentrations include the leaching of parent bedrock from acidic precipitation and an increase of outboard motor use. Most of the current engine blocks are casted from aluminum. The wear and tear of these metal components produce tiny fragments which exit the motor into the water with the dispelled oil.

Despite the surface layer decline, aluminum concentrations analyzed at Beaver Lake fall into the high range of surface sediment concentrations, compared to other analyzed sediment cores in New Hampshire (Table IX-1).

2. Recoverable Cadmium

In the elemental form, cadmium is insoluble in water. It occurs in nature largely as a sulfide salt. Cadmium is used in metallurgy to alloy with copper, lead, silver, aluminum and nickel. It is also used in electroplating, ceramics, photography and in insecticides. Cadmium concentrations measured in Beaver Lake were below 5 mg/kg throughout the sediment profile. This is low compared to some other New Hampshire lake sediments sampled (Table IX-1, Table IX-2, Figure IX-2).

3. Recoverable Copper

Copper salts occur in natural surface waters only in trace amounts, up to about 50 ug/L, and their presence is frequently due to the use of copper sulfate for the control of nuisance plankton species. Copper is used in many alloys, insecticides, fungicides, and wood preservatives.

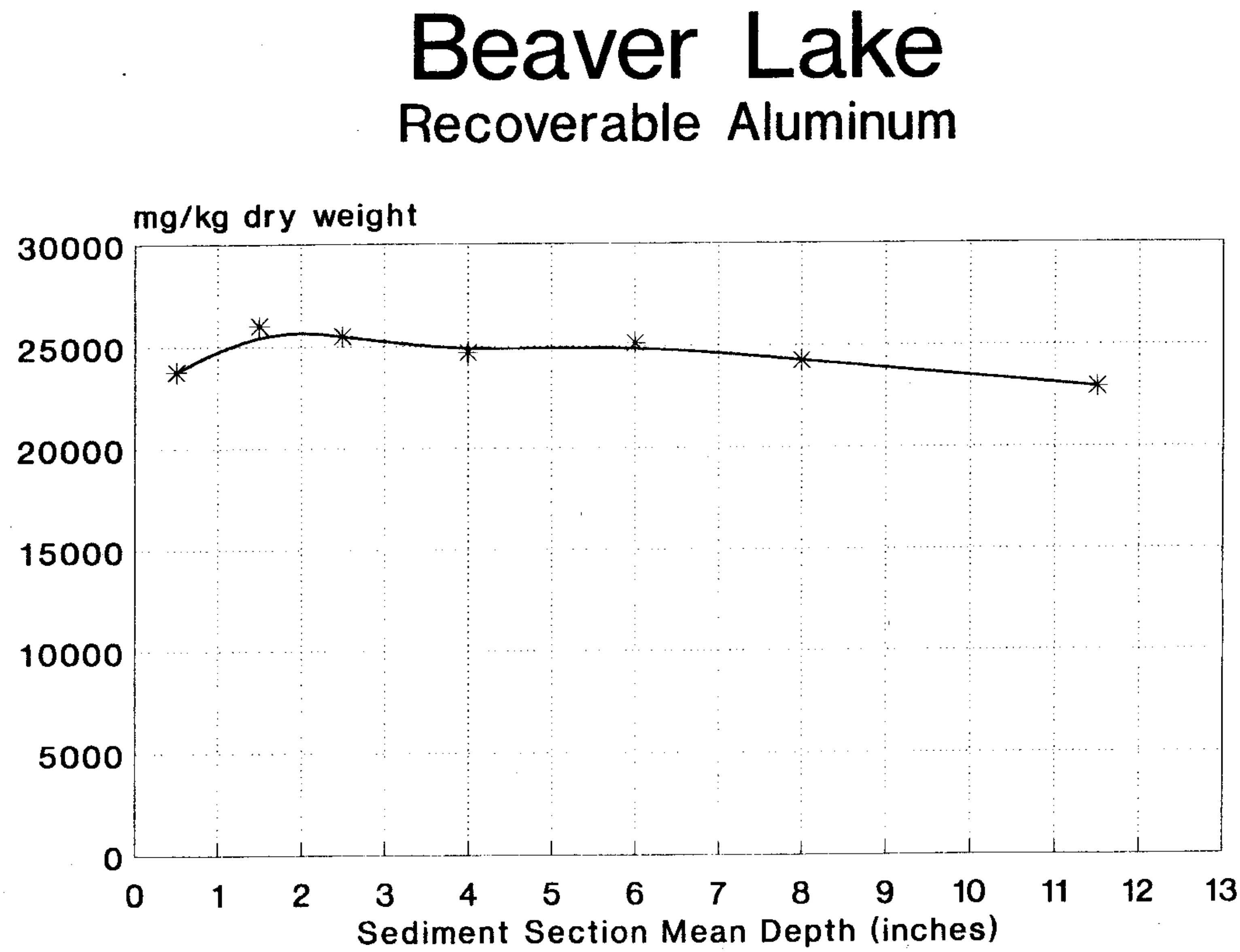


Figure IX-1. Recoverable Al in Beaver Lake Sediments

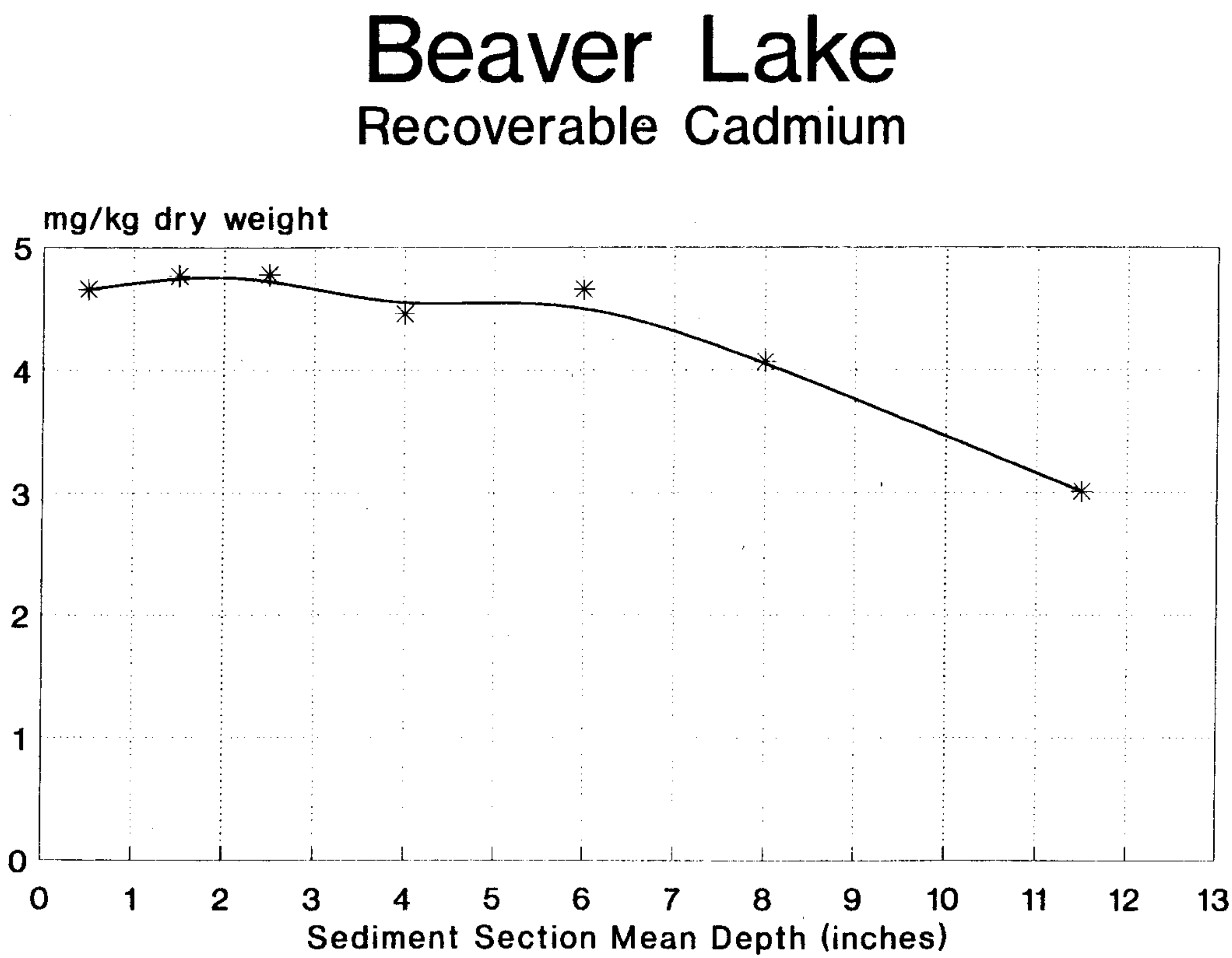


Figure IX-2. Recoverable Cd in Beaver Lake Sediments

Beaver Lake sediment copper concentrations ranged from a low of 16.2 mg/Kg in the 10"-13" layer to a maximum concentration of 28.6 mg/Kg in the 2"-3" layer (Figure IX-3 and Table IX-2). Concentrations measured in all layers of Beaver Lake sediments were similar to other measured concentrations in non-treated New Hampshire lakes (Table IX-1).

4. Recoverable Iron

Iron is the fourth most abundant, by weight, of the elements that make up the earth's crust. Common in many rocks, it is an important component of many soils, especially the clay soils.

Recoverable iron concentrations in Beaver Lake ranged from a minimum of 19,880 mg/kg in the 10-13 inch sediment layer to 26,806 mg/kg in the 1-2 inch section (Table IX-2). Iron concentrations were observed to have increased from the deepest section of the sediment core to just below the surface (Figure IX-4). In comparison with other sediment studies conducted, Beaver Lake sediments contain moderately high concentrations of recoverable iron (Table IX-1).

5. Recoverable Lead

Leaded gasoline, introduced in the 1920's, has been largely blamed for the increased levels of lead observed in the aquatic environment. The solubility of lead compounds in water depends heavily upon pH. Fish kept in water of pH 6.0 concentrate almost three times more lead than fish kept in water of pH 7.5. This is of startling significance for the northeast where lake waters are generally poorly buffered and acid precipitation is further decreasing the pH in many of our lakes and ponds.

Recoverable sediment lead concentrations ranged from a low of 75.7 mg/kg (10-13 inch segment) to 188.6 mg/kg (5-7 inch segment), (see Figure IX-5, Table IX-2). Lead concentration levels were lowest in the bottom four inches of the Beaver Lake sediment core, and increased significantly from the 8 inch to the 4 inch section. Lead concentration levels in the top four inches have declined. Sediment lead found in Beaver Lake is high when compared to other sediment studies conducted in N.H.(Table IX-1).

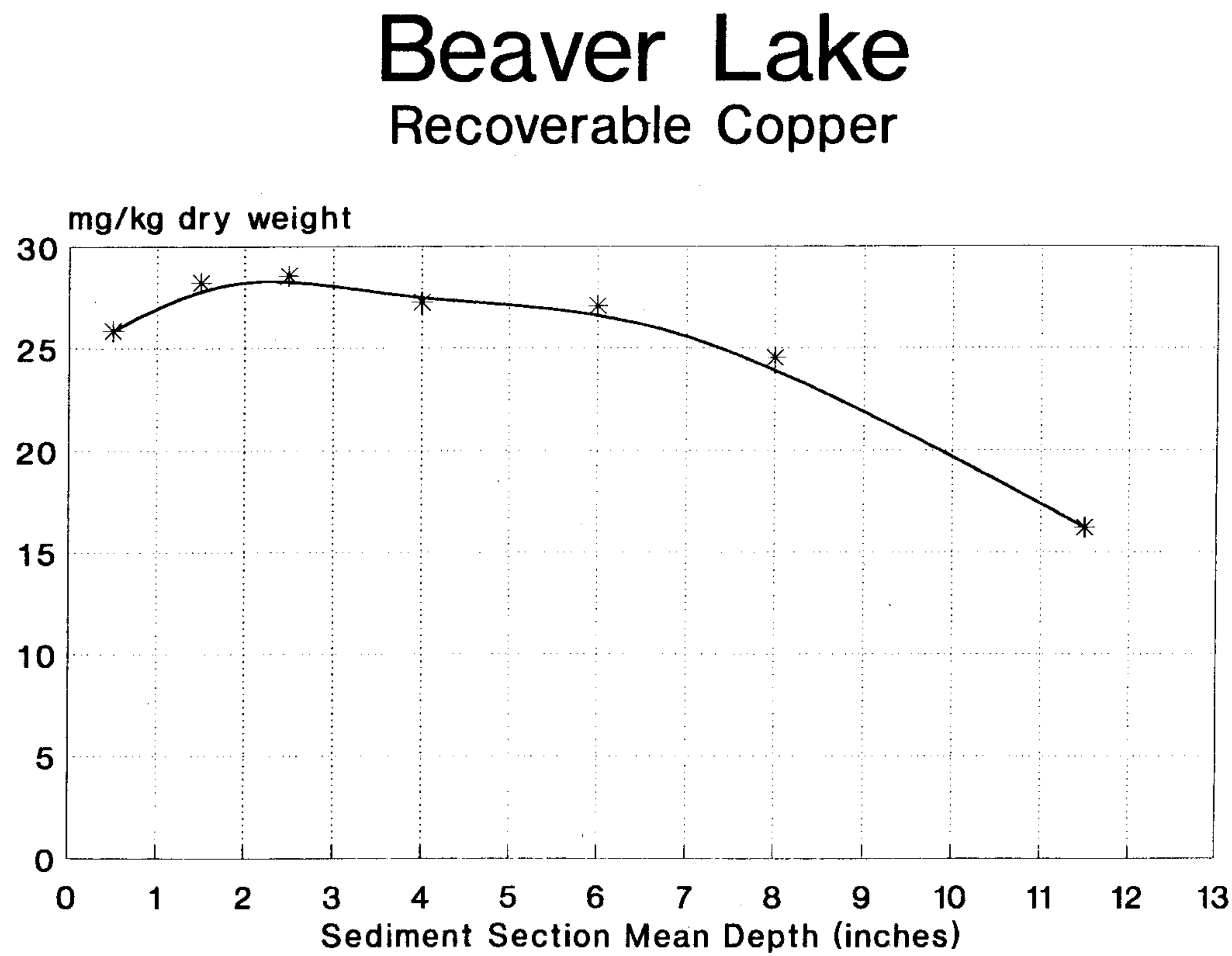


Figure IX-3. Recoverable Cu In Beaver Lake Sediments

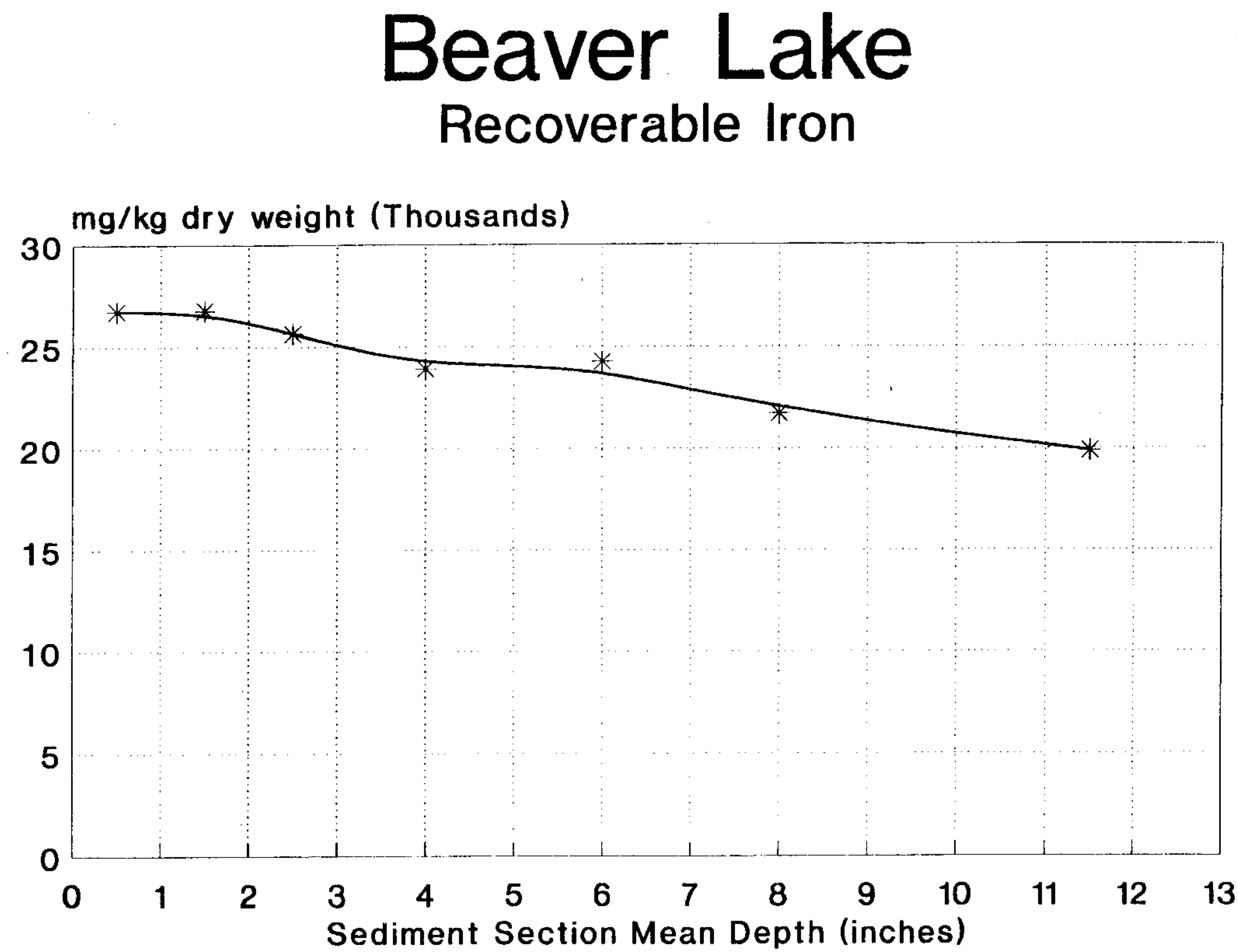


Figure IX-4. Recoverable Fe in Beaver Lake Sediments

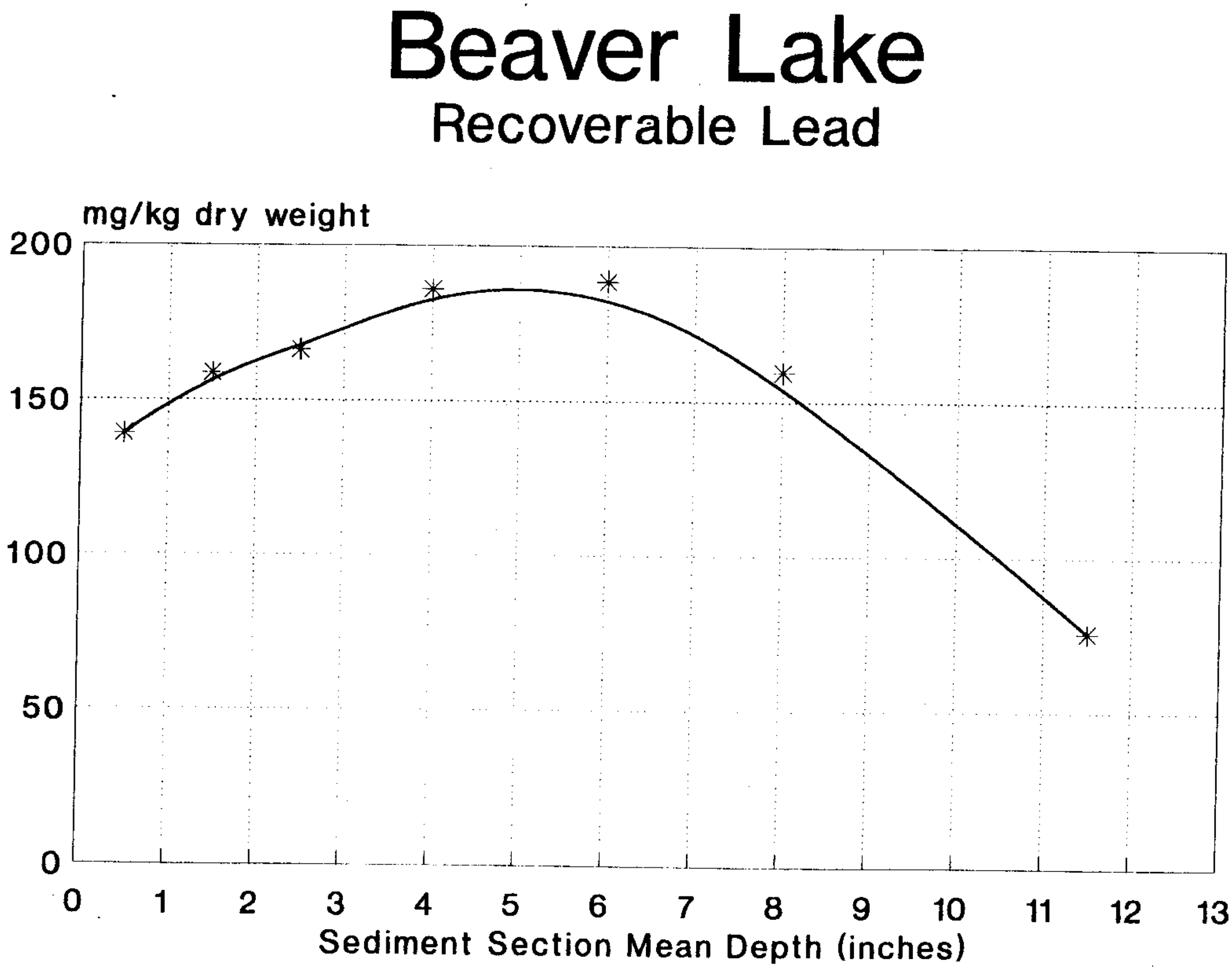


Figure IX-5. Recoverable Pb in Beaver Lake Sediments

6. Recoverable Zinc

Compounds of zinc are soluble in neutral and acidic solutions, so that zinc is readily transported in most natural waters and is one of the most mobile of the heavy metals. Zinc is used for the anti-corrosive coating in galvanized metals and rubber products.

Most of the zinc introduced into the aquatic environment is partitioned into the sediments by sorption onto hydrous iron and manganese oxides, clay minerals, and organic materials. All zinc forms are potentially toxic if they can be sorbed or bound by biological tissue.

Sediment zinc concentrations increased slightly from the deeper sections of the core to the surface portion (Figure IX-6). The lowest concentration (128.7 mg/kg) was found in the deepest section of the core (10-13 inches) and increased steadily to the greatest value (258.1 mg/kg) in the 2-3 inch segment. The concentration then declined at the surface segments. Comparisons of sediment zinc concentrations in other surveys reveal that Beaver Lake has a moderately high levels in the upper sediment sections (Table IX-1).

7. Recoverable Phosphorus

The measurement of phosphorus concentration in a lake gives an indication of the extent of nutrient enrichment. The amount of phosphorus in New Hampshire lakes determines the level of plankton growth. Lake sediments often act as sinks and accumulate high concentrations of phosphorus over long periods of time. Phosphorus which has accumulated in the deep water sediments of a lake may be released into the water when the physical, biological and chemical conditions become conducive for its release. Usually, this release occurs during the summer months. If stratification is weak, this phosphorus migrates to the metalimnion to be utilized by the plankton community; otherwise, much of this hypolimnetic phosphorus is distributed to the entire water column during the fall overturn.

The identification of sediment phosphorus concentration is important to the phosphorus budget. Spatial distribution of sediment phosphorus with depth is important in the evaluation of lake restoration techniques and their feasibility. The uniform distribution of high concentrations of phosphorus throughout the sediment column would obviously make dredging an unfeasible restorative technique. However, sediment sealing with aluminum as a restorative technique might be a solution for this type of problem.

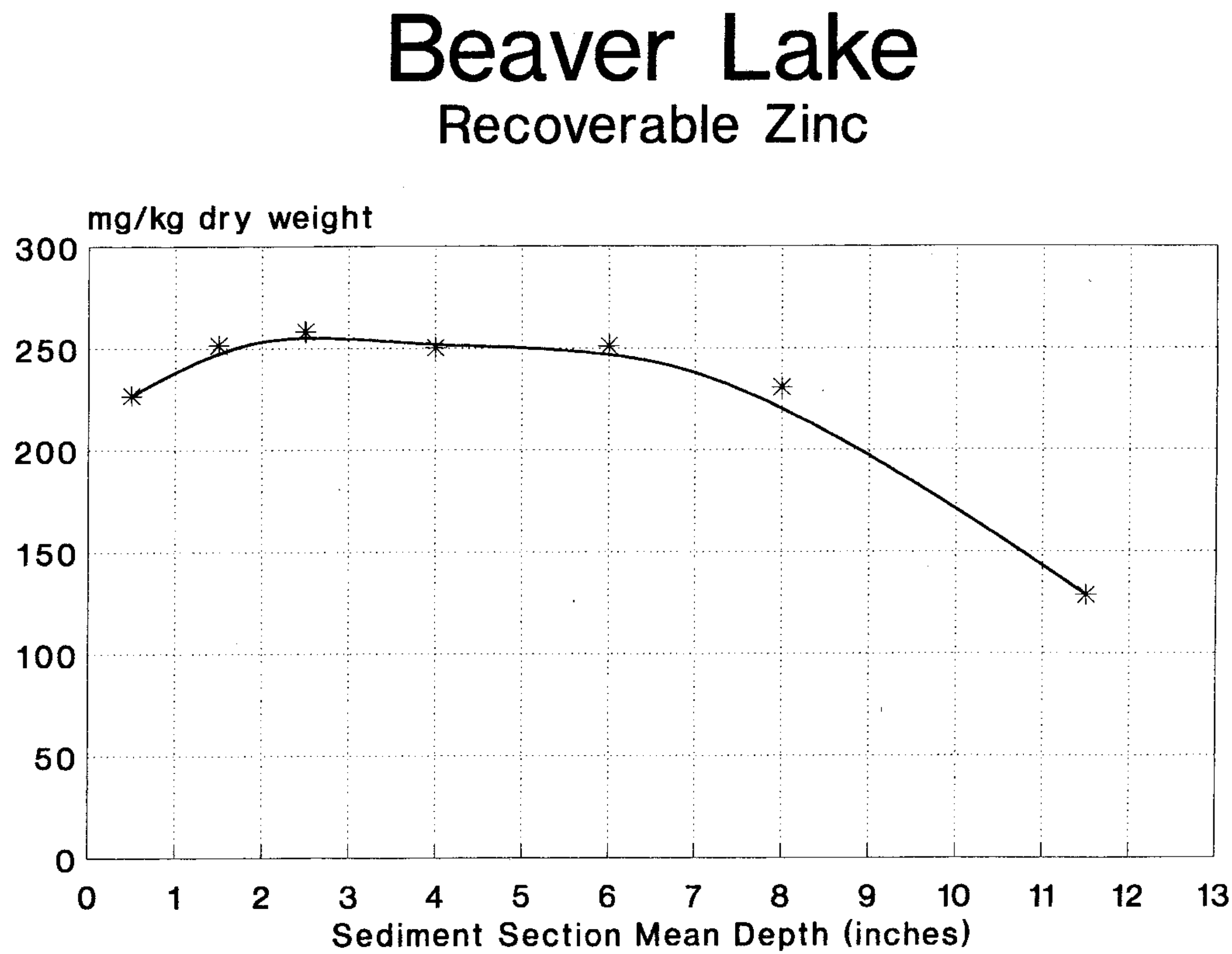


Figure IX-6. Recoverable Zn in Beaver Lake Sediments

Most studies show that lake sediments typically contain 1000-2000 mg/kg of recoverable phosphorus. In twenty-seven borderline mesotrophic/eutrophic lakes located in Massachusetts, the mean concentration was 1,268 mg/kg (personal communication, Mass DEP), while concentrations of recoverable sediment phosphorus in 15 New Hampshire lakes ranged from 100 to almost 14,000 mg/kg. Sediment phosphorus concentrations in Lake Washington, Washington State, (Edmondson, 1972) ranged from 1000 to 6000 mg/kg while the range in Lake Shagawa, Minnesota, was 1000-5000 mg/kg (Larson et al. 1975).

Mean recoverable phosphorus in Beaver Lake (Table IX-2) ranged from 1824 mg/kg(7-10 inch layer) to 2623 mg/kg (1-2 inch layer) (Figure IX-7).

Low concentrations of sediment phosphorus were measured in Beaver Lake when compared to other sediment studies conducted in New Hampshire (Table IX-1).

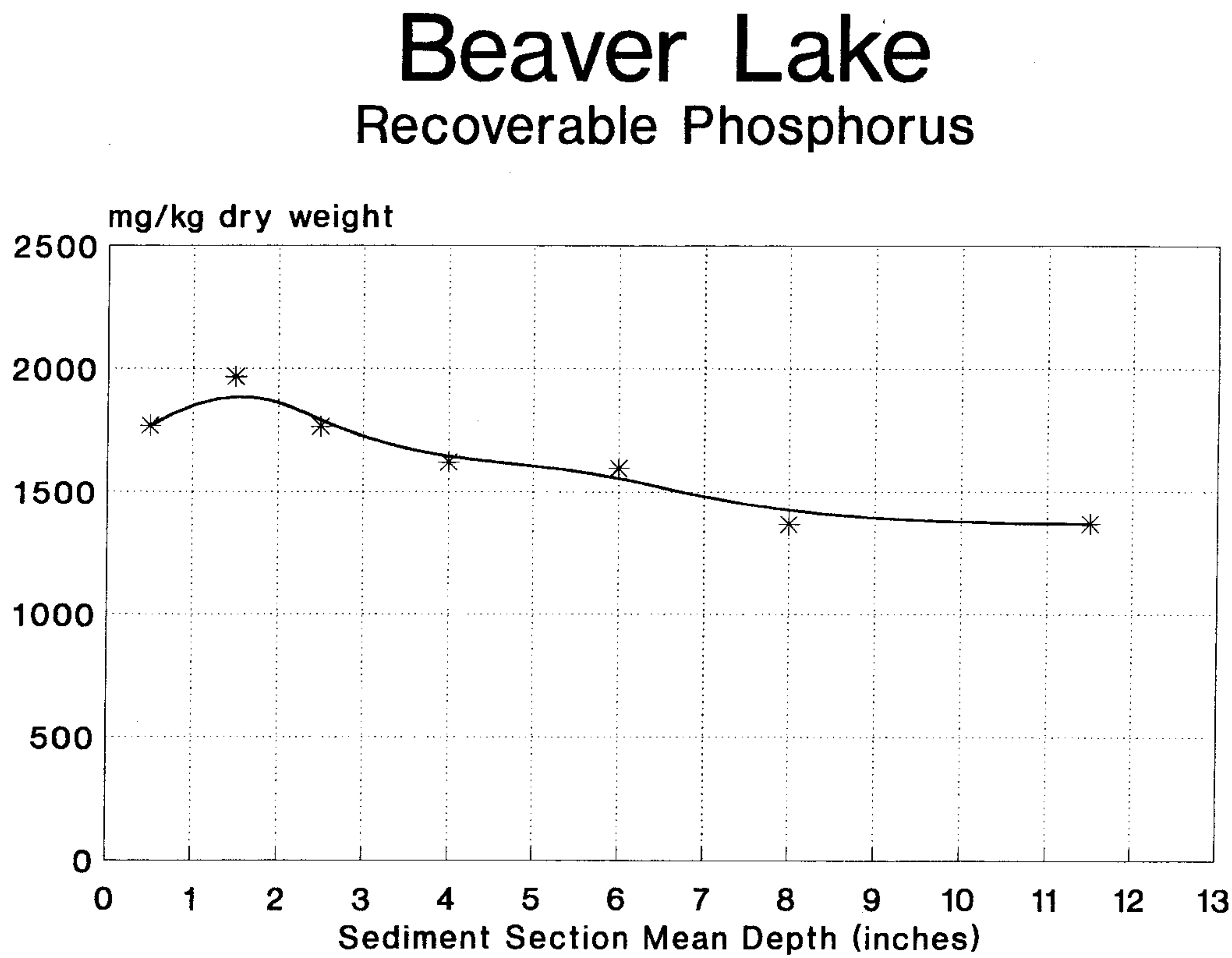


Figure IX-7. Recoverable P in Beaver Lake Sediments

X. TROPHIC STATUS AND PERMISSIBLE LOADINGS

A. Introduction

The trophic status of a waterbody is a hybrid concept referring to the nutritive state (especially phosphorus) of a lake or pond, but is often described in terms of biological activity that occurs as a result of nutrient levels. Trophic state indices have been developed both on the use of a single parameter and on the use of several parameters.

Table X-1, reproduced in part from the EPA Clean Lakes Program Guidance Manual (1980), describes the lake water characteristics of the oligotrophic and eutrophic states. Mesotrophic conditions exist between the limits for eutrophy and oligotrophy.

Table X-1

Summary of Quantitative Definitions of Lake Trophic Status

Characteristics	Oligotrophic	Eutrophy
Total phosphorus (ug/L, summer)	≤ (10 to 15)	≥ (20 to 30)
Chlorophyll-a (ug/L, summer)	≤ (2 to 4)	≥ (6 to 10)
Secchi disk depth (m, summer)	≥ (3 to 5)	≤ (1.5 to 2)

This chapter will examine several trophic classification and permissible loading schemes.

B. Trophic Classification Schemes

1. State of New Hampshire Trophic Classification System

The classification system developed by the Biology Bureau of the New Hampshire Water Supply and Pollution Control Division (Table X-2) utilizes four paramaters (Towne and Estabrook, 1981). Table X-3 lists, for Beaver Lake, the calculated value of each classified parameters for the 1977 and 1984 surveys and the 1991 study year, the trophic points received and the trophic status.

Table X-2

TROPHIC CLASSIFICATION SYSTEM
FOR
NEW HAMPSHIRE LAKES AND PONDS

	TROPHIC POINTS
1. Summer Bottom Dissolved Oxygen:	
a. D.O. $\geq$ 5mg/l	0
b. 2mg/l $\leq$ D.O. $<$ 5mg/l & $<$30 foot depth	1
c. 2mg/l $\leq$ D.O. $<$ 5mg/l & $\geq$30 foot depth	2
d. .5mg/l $\leq$ D.O. $<$2mg/l & $<$30 foot depth	3
e. .5mg/l $\leq$ D.O. $<$2mg/l & $\geq$30 foot depth	4
f. D.O. $<$.5mg/l & $<$30 foot depth	5
g. D.O. $<$.5mg/l & $\geq$30 foot depth	6
2. Summer Secchi Disk Transparency:	
a. $>$ 24 feet	0
b. $>$ 12 feet to 24 feet	1
c. $>$ 6 feet to 12 feet	2
d. $>$ 3 feet to 6 feet	3
e. $>$ 1 foot to 3 feet	4
f. $>$ .5 foot to 1 foot	5
g. $\leq$ .5 foot	6
3. Aquatic Vascular Plant Abundance:	
a. Sparse	0
b. Scattered	1
c. Common	2
d. Abundant	3
e. Very abundant	4
4. Summer Epilimnetic Chlorophyl *a* (mg/M^3):	
a. Chl *a* $<$5	0
b. 5 $\leq$ Chl *a* $<$10	1
c. 10 $\leq$ Chl *a* $<$20	3
d. Chl *a* $\geq$ 20	5

TROPHIC CLASSIFICATION	TROPHIC POINTS STRATIFIED	TROPHIC POINTS *UNSTRATIFIED
Oligotrophic	0-5	0-3
Mesotrophic	6-10	4-6
Eutrophic	11-21	7-15

*Unstratified lakes are not evaluated by the bottom dissolved oxygen criterion.

Table X-3

Trophic Classification of Beaver Lake

Trophic Classification - 1977 Survey

Parameter	Value	Trophic Points
Dissolved Oxygen	0.0 mg/L	6
Secchi Disk	4.8 m	1
Plant Abundance	very abundant	4
Chlorophyll-a	3.28 mg/m^3	0
	Total	11
Trophic Status		Eutrophic

Trophic Classification - 1984 Survey

Parameter	Value	Trophic Points	Trophic Points (Revised)
Dissolved Oxygen	0.0 mg/L	6	6
Secchi Disk	3.4 m	2	2
Plant Abundance	abundant	3	5
Chlorophyll-a	7.02 mg/m^3	1	1
	Total		14
Trophic Status		Eutrophic	Eutrophic

Revised Trophic Classification - 1990 Study Year

Parameter	Value	Trophic Points
Dissolved Oxygen	*0.0 mg/L	6
Secchi Disk	*4.0 m	2
Plant Abundance	common/abundant	4
Chlorophyll-a	*8.12 mg/m^3	2
	Total	14
Trophic Status		Eutrophic

*Mean value

Beaver Lake received a total of 11 trophic points in 1977 and 12 total points in 1984, classifying it as eutrophic. During that period of time, chlorophyll-a increased, transparency decreased and the aquatic plant growth slightly declined.

The system used to trophically classify New Hamsphire lakes and ponds was revised in 1989 (Table X-4). The purpose of the revision was to provide for equal points under each attribute and to reduce the impact of the bottom dissolved oxygen criterion. Unlike the previous system, the extent of oxygen depletion is evaluated in the new system.

The revised classification system was applied to the 1985 survey data to compare the two systems. In both instances Beaver Lake was classified as eutrophic. The data from the 1990 summer sampling period was compiled to determine trophic status using the revised classification system and incorporating many sampling dates. Once again it fell into the eutrophic status.

2. Carlson's Trophic State Index

Carlson's (1977) TSI system is based on Secchi depth as a means of characterizing algal biomass. This parameter, in the absence of turbidity and colored materials in water, is a direct measure of "plankton-algal manifested eutrophication processes" in natural waters. Its range of values can easily be transformed into a convenient scale. Further, by using empirically derived relationships between Secchi depth and both phosphorus and chlorophyll-a concentration, Carlson derived equations to estimate the same index value from these two parameters as well as from Secchi depth. Carlson's trophic index is basically a linear transformation of Secchi depth, such that each major unit in his scale has half the value of the next lowest unit. Conversely, for total phosphorus and chlorophyll-a, each major unit in his scale has larger values for the next higher unit. The computational form of the equations for his trophic scheme is as follows:

$$TSI(SD)=10\left(6-\frac{\ln SD}{\ln 2}\right)$$

$$TSI(TP)=10\left(6-\frac{\ln \frac{48}{TP}}{\ln 2}\right)$$

$$TSI(Chl)=10\left(6-\frac{2.04-0.68\ln Chl}{\ln 2}\right)$$

Table X-4

Trophic Classification System for New Hampshire Lakes and Ponds (Revised 1989)

TROPHIC POINTS

1. Summer Bottom Dissolved Oxygen (mg/L):

a. D.O. >4 mg/L	0
b. D.O. = 1 to 4 mg/L & hypo. vol. ≤ 10% lake vol	1
c. D.O. = 1 to 4 mg/L & hypo. vol. > 10% lake vol	2
d. D.O. <1 mg/L in <1/3 hypo. vol. & hypo. vol. ≤ 10% lake vol	3
e. D.O. <1 mg/L in ≥1/3 hypo. vol. & hypo. vol. ≤ 10% lake vol	4
f. D.O. <1 mg/L in <1/3 hypo. vol. & hypo. vol. > 10% lake vol	5
g. D.O. <1 mg/L in ≥1/3 hypo. vol. & hypo. vol. > 10% lake vol	6

2. Summer Secchi Disk Transparency (M):

a. >7m	0
b. >5m - 7m	1
c. >3m - 5m	2
d. >2m - 3m	3
e. >1m - 2m	4
f. >.5m -1m	5
g. ≤.5m	6

3. Summer Vascular Aquatic Plant Abundance:

a. Sparse	0
b. Scattered	1
c. Scattered/Common	2
d. Common	3
e. Common/Abundant	4
f. Abundant	5
g. Very Abundant	6

4. Summer Epilimnetic Chlorophyll a (mg/m^3):

a. < 4	0
b. 4 - < 8	1
c. 8 - < 12	2
d. 12 - < 18	3
e. 18 - < 24	4
f. 24 - < 32	5
g. ≥32	6

TROPHIC CLASSIFICATION	TROPHIC POINTS STRATIFIED	TROPHIC POINTS *UNSTRATIFIED
Oligotrophic	0 - 6	0 - 4
Mesotrophic	7 - 12	5 - 9
Eutrophic	13 - 24	10 - 18

*Lakes with no hypolimnion are not evaluated by the bottom dissolved oxygen criterion.

where:

SD = Secchi depth (m)

TP = Total phosphorus concentration (mg/M^3) and

Chl-a = Chlorophyll-a concentration (mg/M^3)

According to Carlson (1977), this index system has the advantages of easily obtained data, simplicity absolute TSI values, valid relationships, retrieval of data from the index, and can be grasped by the layman in much the same manner as the Richter earthquake scale. The TSI incorporates most lakes in a scale of 0 to 100 as Figure X-1 demonstrates. Each major division (10, 20, 30, etc.) represent a doubling of algal biomass.

Results of the Carlson TSI were obtained by substituting summer mean Secchi depth, chlorophyll-a, and phosphorus values from Beaver Lake into the equations to compute the TSI. Table X-5 shows the mean summer values, the TSI number and the classification for each measured parameter. The chlorophyll-a values observed at Beaver Lake reflect moderate to high concentrations that would be observed in a mesotrophic/eutrophic lake or pond. Median Secchi disk observations were representative of mesotrophic conditions. An examination of mean summer in-lake phosphorus concentrations, for the epilimnion/hypolimnion, showed a Carlson ranking of mesotrophic for the epilimnion, and mesotrophic for the hypolimnion.

Table X-5
Carlson Trophic Classification
for Beaver Lake

Parameter	Mean Summer Value	Trophic Points	Classification
Chlorophyll-a (mg/m^3)	8.12	51	Mesotrophic/Eutrophic
Secchi Disk (m)	4.0	40	Mesotrophic
Phosphorus (ug/L)	Epi. 10	37	Mesotrophic
	Hypo. 20	47	Mesotrophic

Carlson's Trophic State Index

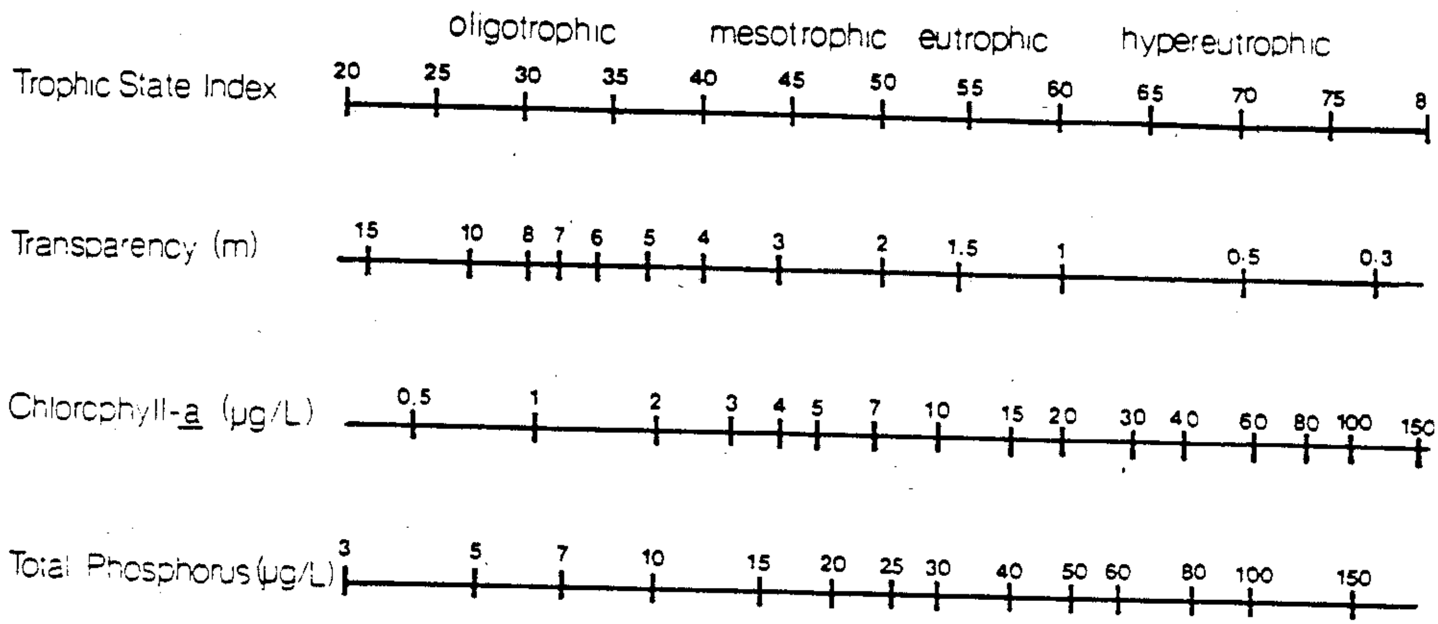


Figure X-1. Carlson's Trophic State Index Scale.

3. Dillon & Rigler Permissible Loading Model

Mathematical models can also be useful both in diagnosing lake problems and evaluating potential solutions. They represent in quantitative terms the cause-effect relationships that determine lake quality. In some cases, the determination of the trophic state of a lake involves a comparison of actual phosphorus loading to the lake with a maximum permissible loading that the lake can tolerate before excessive weed and algae growth occurs and transparency diminishes. The trophic model developed by Dillon/Rigler (1975) has been widely utilized and well documented by researchers. Its application classifies a lake as oligotrophic, mesotrophic or eutrophic by comparing calculated actual loadings with permissible annual loadings. The tolerance of the lake to phosphorus loading is predicted as function of two morphological parameters, mean depth (z) and water retention time (T), which have been proven by several researchers to be the primary determinants of loading permissibility. Additionally, the model considers the phosphorus retention in the lake sediments. The retention coefficient (R) may be empirically calculated from morphological data or may be derived from a definitive phosphorus budget.

Table X-6 shows the qualitative relationship between the model input parameters and phosphorus loading tolerance.

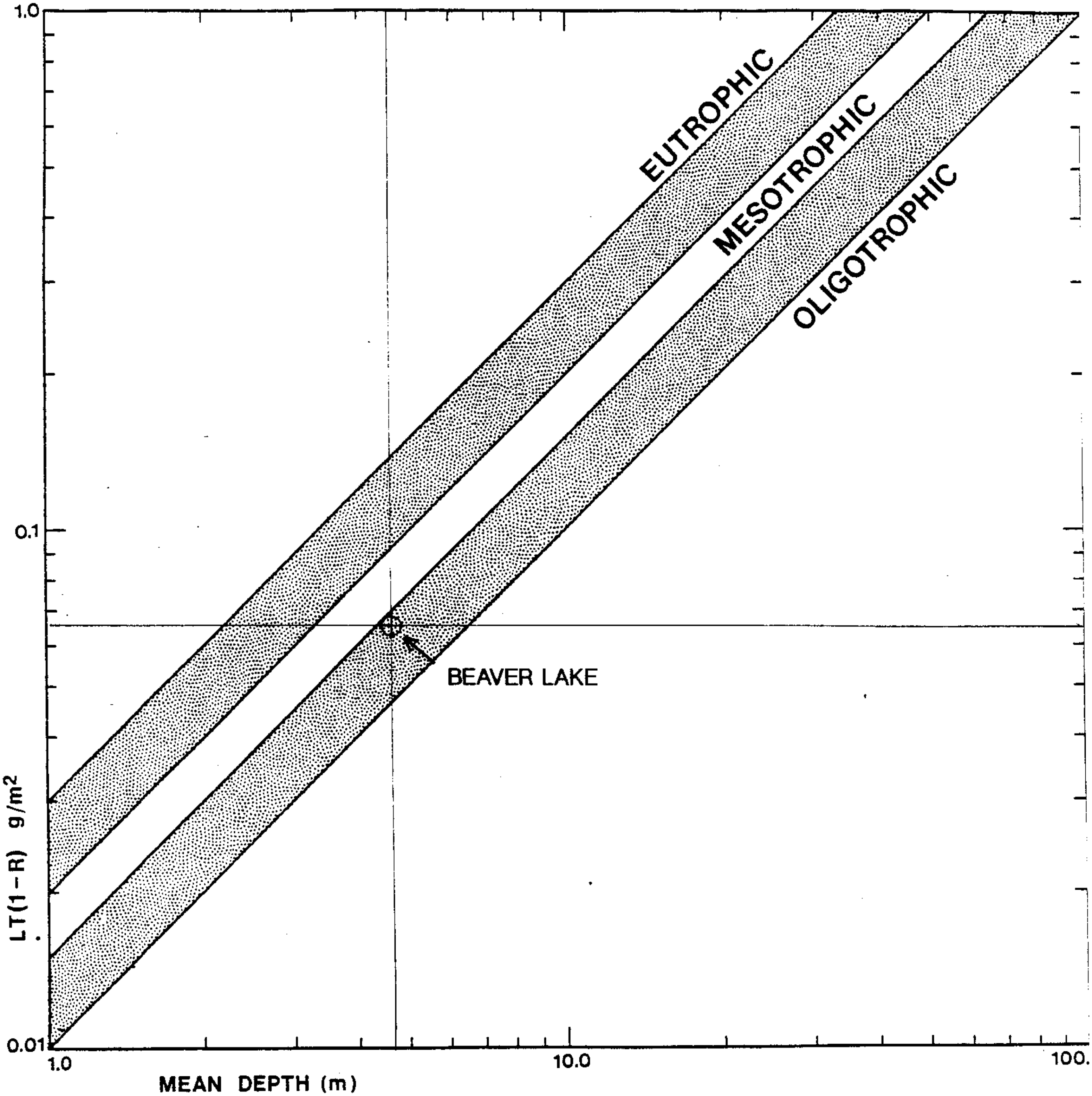
Table X-6

Dillon/Rigler Permissible Loading Tolerance

High Phosphorus Loading Tolerance	Low Phosphorus Loading Tolerance
*Large mean water depth	*Small mean water depth
*Rapid flushing rate	*Slow flushing rate
*High sediment retention	*Low sediment retention

Thus, existing trophic status is set by existing values for these parameters and annual phosphorus loading. Similarly, historical trophic status can be determined from estimates of previous phosphorus loading. The degree of trophic state improvement, which would result from the implementation of watershed and in-lake management strategies, can be gauged from predicted changes of loading and morphology. Table X-7 presents the Dillon/Rigler trophic status calculations for Beaver Lake. Figure X-2 is a

Figure X-2



L = AREAL PHOSPHORUS LOADING ($g/m^2/yr$)
R = PHOSPHORUS RETENTION COEFFICIENT (DIMENSIONLESS)
T = HYDRAULIC RETENTION TIME (yr)

DILLON/RIGLER TROPHIC STATUS

graphical representation of the Dillon/Rigler model showing trophic zones, plotted on axes of mean depth and areal loading (Table X-7) with the data point for the Beaver Lake study year.

Table X-7
Dillon/Rigler Trophic Status Calculations

Parameter	Calculation
Lake area (m^2)	540,700
Mean z (m)	4.83
Total loading (Kg)	542
Flushing rate (yr^{-1})	7.76
Water retention time (yr) T	0.129
P coefficient R	0.49
Total areal loading ($g/m^2/yr$) L	1.00
LT (1-R) (g/m^2)	0.066

The solution of the Dillon/Rigler equation for Beaver Lake data (unaltered morphology) shows the existing oligotrophic/mesotrophic boundary to exist between 390 and 614 $kgPyr^{-1}$ and the mesotrophic/eutrophic boundary to exist between 797 and 1278 $kgPyr^{-1}$. These boundaries for loadings are based on a mean depth (z) of 4.8 m, a water retention time (T) of 0.13 yr and a phosphorus retention coefficient (R), derived from the phosphorus budget, of 0.49. The actual budgeted phosphorus loading for the study year at Beaver Lake was 542 $kgPyr^{-1}$, which classifies the lake as Mesotrophic. The model predicted that Beaver Lake received 541 $kgPyr^{-1}$. The Dillon/Rigler model demonstrates that an increased load of 255 $kgPyr^{-1}$ would decrease the lake quality enough to place Beaver at the mesotrophic/eutrophic borderline. It would take an increase of 736 $kgPyr^{-1}$ to place Beaver Lake into the eutrophic lake classification.

The Dillon/Rigler model also predicts in-lake phosphorus concentration. Utilizing the Dillon/Rigler equation $P=Lp/qs(1-R)$, the calculated predicted in-lake phosphorus concentration for Beaver Lake was 0.014 mg/L. This predicted value compares slightly lower with an actual study year mean hypolimnetic phosphorus concentration of 0.020 mg/L and slightly higher than the study year mean epilimnetic phosphorus concentration of 0.010 mg/L. The actual mean epilimnetic phosphorus concentration was calculated from the summer phosphorus data collected by the Biology Bureau during the 1990 sample year.

4. Vollenweider Phosphorus Loading and Surface Overflow Rate Relationship

The Vollenweider model is based on a five year study involving the examination of phosphorus load and response characteristics for about 200 waterbodies in 22 countries in Western Europe, North America, Japan and Australia. Vollenweider, working on the Organization for Economic Cooperation and Development (OECD) Eutrophication Study, developed a model describing the relationship of phosphorus load and the relative general acceptability of the water for recreational use (Vollenweider, 1975). Vollenweider found that when the annual phosphorus load to a lake is plotted as a function of the quotient of the mean depth and hydraulic residence time, lakes which were eutrophic tended to cluster in one area and oligotrophic lakes in another (Figure X-3, from Flanders, 1986 and Connor, et al 1992).

Vollenweider developed a statistical relationship between areal annual phosphorus loading to a lake normalized by mean depth (2) and hydraulic residence time (T), to predict phosphorus lake concentration. Table X-8 summarizes the Vollenweider model parameters for the Beaver Lake sample year.

Table X-8

Vollenweider Phosphorus Concentration Prediction

Parameter	Equation	Beaver Lake
1. Hydraulic residence time T	T=V/Q	0.13 yr
2. Surface overflow rate (qs)	qs=z/T	37.4 (m/y)
3. Areal phosphorus	P load/lake surface area	1.00 ($g/m^2/y$)
4. Phosphorus concentration prediction	(Lp/qs) [1/(1+ z/qs)]	0.020 (mg/L)

OECD DATA / VOLLENWEIDER PLOT

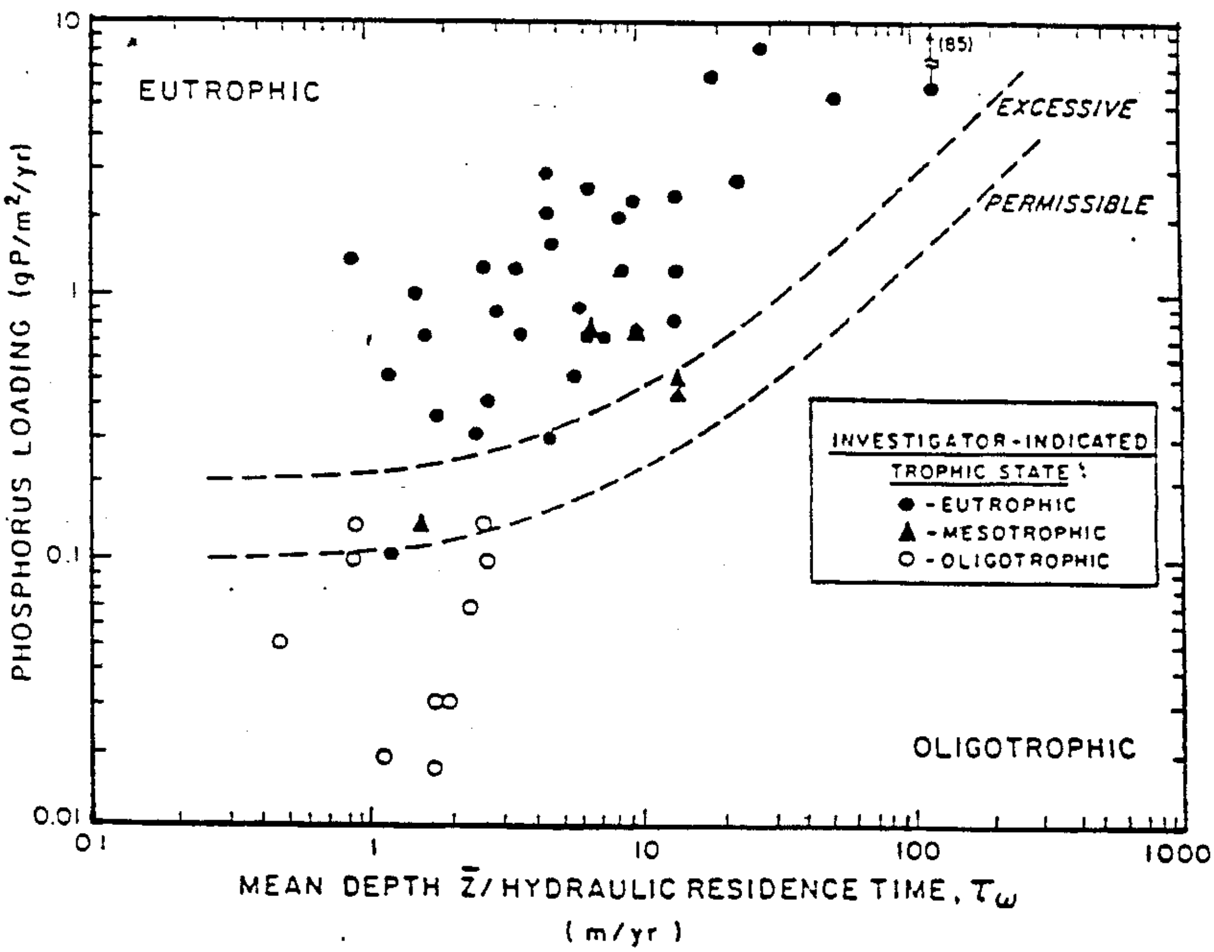


Figure X-3. OECD Data and the Vollenweider Plot.

Thus, based on the physical constraints that control water volume, the hydraulic residence time in the lake, and mean lake depth, combined with phosphorus loading, the Vollenweider model predicts the existing in-lake phosphorus concentration to be 0.024 mg/L in Beaver Lake. An examination of actual mean epilimnetic in-lake phosphorus concentrations during the 1990 summer study period, revealed that the mean measured phosphorus concentration of 0.010 mg/L was lower than the predicted value of 0.024 mg/L. However, the predicted phosphorus value compared favorably with the mean summer hypolimnetic phosphorus value of 0.020 mg/L.

Figure X-4 graphically portrays the measured loading rates for Beaver Lake and compares the lake with other studied lakes in New Hampshire. Based on the permissible and excessive loading curves, it can be seen that Beaver Lake lies in the mesotrophic/eutrophic zone, in the vicinity of the excessive loading range.

C. Trophic Classification Summary

A summary of the four classification schemes utilized in this study (Table X-9) shows that the New Hampshire Lake classification system classifies Beaver Lake as eutrophic. The Dillon/Rigler model and Vollenweider Phosphorus Loading model classifies Beaver Lake as mesotrophic and mesotrophic/eutrophic respectively. The Carlson Trophic Status Index defines a trophic class for several parameters. Secchi disk transparency measurements in Beaver Lake and phosphorus concentration fell into the mesotrophic range, while chlorophyll-a measurements were in the mesotrophic/eutrophic range.

On a permissible loading basis, the Dillon/Rigler model demonstrates that it would take an increased load of 255 $kgPyr^{-1}$ to decrease the lake quality enough to reflect characteristics of borderline mesotrophic/eutrophic conditions.

D. Predicting the Capacity of a Lake for Development

New Hampshire has experienced significant growth and development in the last two decades and is likely to continue to see such growth into the 1990's. This growth has greatly increased pressures on one of the very features that has attracted people to the state -- the lakes. While new development, both year-round and seasonal, and conversion/expansion of existing development allow more people to enjoy these resources, it also can threaten the quality of a lake environment.

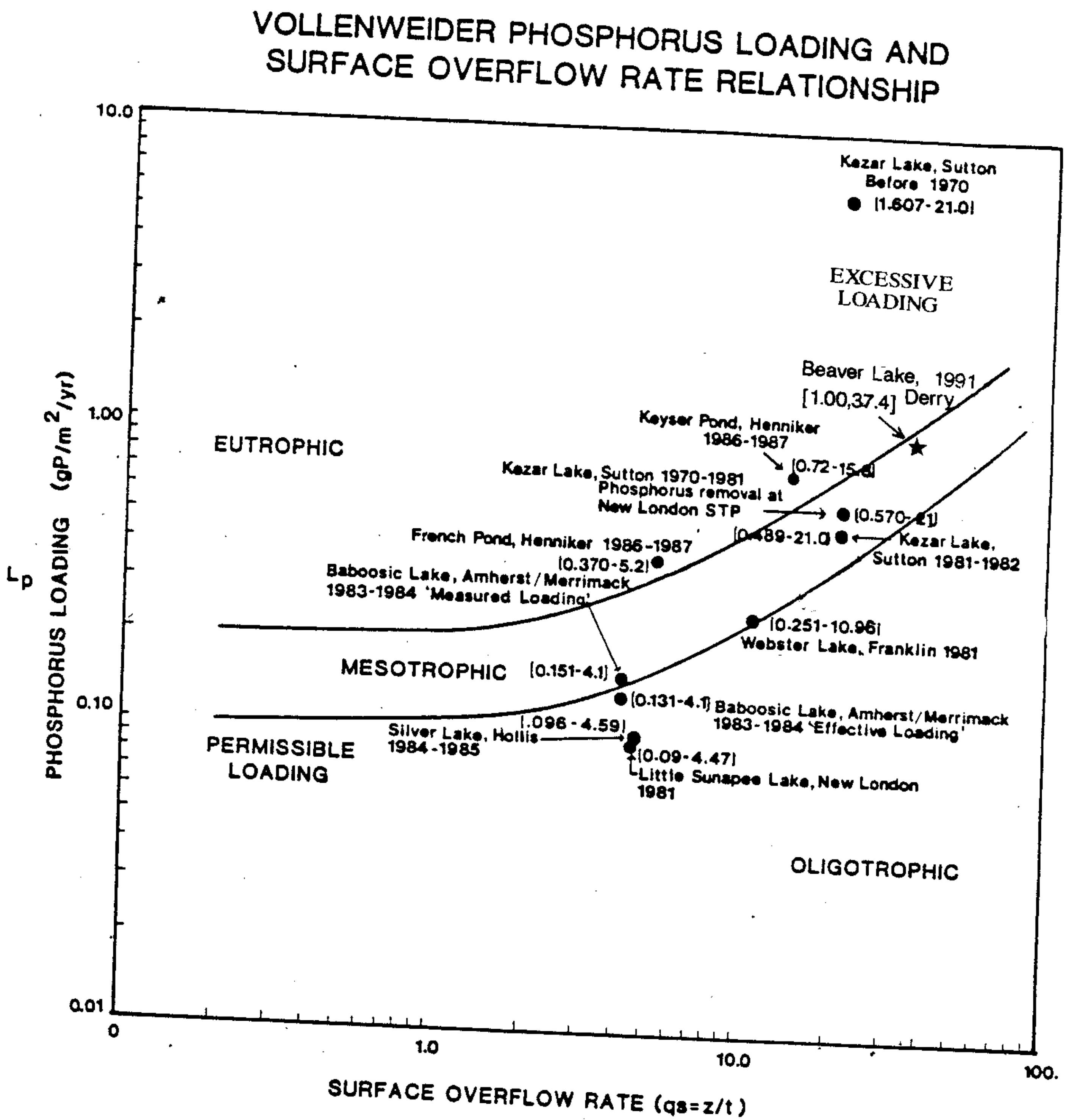


Figure X-4. Vollenweider Phosphorus Loading and Surface Overflow Rate Relationship.

Table X-9

Trophic Classification Summary

Classification Model	Trophic Classification Beaver Lake
1. New Hampshire Lake Classification	Eutrophic
2. Carlson's TSI	
Chlorophyll-a	Mesotrophic/Eutrophic
Secchi Disk	Mesotrophic
Phosphorus (Epilimnion)	Mesotrophic
Phosphorus (Hypolimnion)	Mesotrophic
3. Dillon/Rigler	Mesotrophic
4. Vollenweider	Mesotrophic/Eutrophic

A predictive computer model has been utilized to aid in quantifying the environmental impacts of development on a lake. This model, which measures the phosphorus loading to a lake resulting from the surrounding development, predicts the capacity of the lake for seasonal and/or permanent development that will not threaten existing lake quality. Utilizing available data on the particular lake of interest and relying on several conservative assumptions about phosphorus impacts from certain kinds of development, the model presents the results in the form of a maximum number of allowable units of development around the lake. This number is intended as a guide for local officials in evaluating the impacts of proposed development on lakes.

Phosphorus (P) is the nutrient most frequently controlling lake productivity and, therefore, trophic status in New Hampshire lakes. Therefore, predictions concerning the impact of development on the phosphorus concentration of a lake, and subsequently on parameters describing the trophic state, are central to a predictive management scheme. From the geology and land use considerations of a lake's drainage basin, it is possible to estimate the total phosphorus exported or washed out per unit area of watershed. When combined with the drainage area, this provides an estimate of the total phosphorus supplied to the lake from the land. The addition of phosphorus input from direct lake precipitation determines the natural phosphorus load to the lake. Existing development -- both year-round and seasonal -- is then measured (tax maps or field counts with the assistance of local officials), and the phosphorus loading from artificial sources is calculated with the assistance of certain coefficients and conservative assumptions. The total P loading, natural plus artificial, may then be combined with the lake morphometry (general physical characteristics -- size, depth, etc.) and water budget to predict a phosphorus concentration that is subsequently related to the average summer chlorophyll-a concentration. Chlorophyll-a is an indication of the planktonic algal biomass in the lake and is directly proportional to the phosphorus inputs. From the chlorophyll calculation one can calculate the lake clarity or Secchi disk transparency. Finally, the maximum permissible artificial loading that will not lower lake quality in terms of chlorophyll-a or water clarity can be estimated. This maximum is expressed as the maximum of allowable development units (i.e., number of cottages).

This model is designed to predict the capacity of a lake for development without utilizing actual water quality data. In the case of Beaver Lake the immediate shoreland area has been recently sewered eliminating much of the artificial leachfield phosphorus loading to the lake. Although it is possible for additional sewered development to occur around Beaver Lake, we urge that best shoreland protection practices be utilized minimizing impervious structures or the use of untreated urban runoff. The feasibility section of this report discusses lake protection and non-point sources of pollution to Beaver Lake in greater detail.

CHAPTER XI

FEASIBILITY OF RESTORATIVE ACTIONS

A. Overview

The subject of lake restoration and lake protection has been debated and researched extensively in the past decade. Although the need to do something about our degraded lakes is beyond dispute, the science of lake restoration is still in its infancy. Often, a judgement must be made about feasible limits of expenditure and effort without the reassurance of a solid basis for predicting results.

Once a project for lake restoration is undertaken, the results of this effort must be carefully monitored, evaluated and recorded.

Although lakes differ biologically, chemically, and physically, so that one method may bring gratifying results in one lake and not in another, permanent lake rehabilitation begins with halting the introduction of undesirable substances.

Most successful lake restoration project are easily appreciated by people familiar with the "before". A lake restored to health and beauty is an irresistibly exhilarating sight.

The previous sections of this report constitute a diagnostic study of Beaver Lake and it's watersheds. They describe the water quality problems and the sources and levels of the nutrients causing those problems. This section deals with the feasibility of implementing a variety of techniques to help reduce the problems that do exist and to protect the lake in the future.

Techniques that are available for lake restoration and protection are commonly grouped into two basic types: Those that attack the cause of the problem and those that attempt to mitigate the effects of the problem. While both approaches may sometimes have to be utilized, those that attack the cause of the problem are the only long-term solutions.

B. Problem Treatment

1. Algaecide Treatment

The use of the algaecide copper sulfate in New Hampshire lakes was once quite common in relieving dense phytoplankton blooms. Although the method does not reverse the lake's eutrophication trend, it temporarily alleviates nuisance algal blooms and provides an acceptable recreational season. In recent years, the use of copper sulfate as an algaecide has been limited, for the most part, to the treatment of municipal water supplies.

Historically, Beaver Lake supported nuisance blue-green (Cyanobacteria) plankton blooms during the recreational season and dense populations of diatoms (Bacillariophyceae) and golden brown algae (Chrysophyceae) during the remaining months. The recreational season, from June through August, has proven to be a time of excessive chlorophyll-a concentrations, low transparency measurements, unsightly surface scums, obnoxious odors, and generally poor aesthetic conditions.

Although applications of copper sulfate are no longer widely used to reduce algal blooms in recreational ponds, this study must nonetheless evaluate the cost of treating Beaver Lake with the chemical, in case copper sulfate is utilized as pre-treatment for an accepted restoration technique.

If copper were to be utilized for pre-treatment in Beaver Lake, the effective calculated chemical dosage would be approximately 722 pounds. The price of copper sulfate may vary, but a reasonable current price for copper sulfate is approximately $0.70 per pound. At these prices, one could expect the chemical cost of treating Beaver Lake to be in the $500 range. The labor for this application would require two field persons working eight hours at approximately $50.00 per hour or $800.00. Adding the costs of permit applications, equipment and travel costs of those individuals treating the pond, the total cost to apply copper sulfate to Beaver Lake would probably be in the $2,000 to $2,500 range.

2. Artificial Circulation

Artificial circulation and hypolimnetic aeration are management techniques for oxygenating lakes subject to water quality problems such as algal blooms and fishkills. Artificial circulation is achieved by injecting diffused air into the lower waters, by mechanical pumping of water from one depth stratum to another, or by inducing turbulence at the surface using large axial-flow pumps. Complete mixing leads to homogenous conditions throughout the water column (Pastorak, Ginn and Lorenzen, 1981).

Whole lake mixing may reduce regeneration of nutrients from profundal sediments, which may control blooms of blue-green algae. The elevation of epilimnetic CO_2 by destratification often causes a reduction in pH sufficient enough to shift algal communities from nuisance blue-green species to a mixed assemblage of green algae. While hypolimnetic treatment usually decreases phosphorus concentration in the bottom waters, the long term effects on internal loading of nutrients is unknown.

The New Hampshire Water Supply and Pollution Control Commission (NHWSPCC) installed and operated an artificial aeration system within Kezar Lake from July, 1968 through August of 1974. The selected destratification system forced compressed air from four shore-located compressors through two-inch I.D., P.V.C. plastic piping to a terminal series of ceramic diffusers located on the bottom at the deepest point in the lake (8.0 meters) (Towne, 1970). Towne reported that Kezar Lake's visibility improved from one foot (0.3 m) to four feet (1.2 m), hypolimnetic dissolved oxygen increased, temperature increased, total plankton numbers declined, and blue-green algae populations declined. Destratification was therefore declared a success in its first season of operation. Destratification continued to operate successfully through the 1971 sampling season. However, the effectiveness of the destratification process was considered somewhat less successful during the 1972 summer season.

In 1974, Kezar Lake once again experienced a bloom of blue-green *Aphanizomenon*, despite ongoing destratification processes. The *Aphanizomenon* bloom lasted nine weeks, increasing chlorophyll-*a* concentrations to over 100 mg/m^3, increasing cell counts over 500,000 cells mL^{-1}, and decreasing transparency to 0.5m.

By the end of the 1974 season, destratification was deemed by the biological investigators as no longer effective for improving water quality and transparency in Kezar Lake. Biologists speculated the blue-green algae had somehow adapted to the annual lake circulations, enabling them once again to aesthetically reduce the lake's recreational value.

Kezar Lake was destratified for seven consecutive summer seasons, at a cost of $27,000. This treatment procedure was instituted as a temporary measure to control the phytoplankton blooms until phosphorus removal facilities (tertiary treatment) could be constructed at the New London sewage treatment plant. It provided a limited relief for the first few years, but almost no effect on controlling the phytoplankton blooms the last two years of operation (NHWSPCC Staff Report No. 79, 1976).

In other applications of the technique, highly variable results from case to case have occurred. In most instances, problems with low dissolved oxygen have been solved. In about half the cases, and where very small temperature differences from top to bottom have been maintained all summer, algal blooms have been reduced (Pastorak *et al*. 1981; Cooke *et al*. 1986). In other cases, phosphorus and turbidity have increased and transparency decreased.

Failure to achieve the desired objective is often due to an underpowered air compressor. Lorenzen and Fast (1977) concluded that there must be less than 2-3°C difference from top to bottom of the lake in order to achieve improvement in algal biomass. This requires an air flow of at least 30 ft^3 of air per thousand ft^2 (2.3 acres) of lake surface.

Artificial circulation has been recommended as an inexpensive, efficient restoration technique (Pastorak et al., 1981). Cost information on a project basis is scarce. However Lorenzen and Fast (1977) cite an annual cost of $113,000 (1983 dollars) for two air compressors producing air at 1200 ft^3 min-1. This includes pipes and air diffusers. At the recommended rate of 9.2 $m^3\ min^{-1}\ Km^{-2}$, this represents a cost of $303 ha^{-1}, which is modest in comparison to other restoration techniques. Much of the first year costs will be primarily for the compressor and installation of pipes and diffuser.

3. Hypolimnetic Aeration

Hypolimnetic aeration is different than artificial circulation in objective and operation. Artificial circulation employs a curtain of bubbles to achieve complete mixing and isothermal conditions, while hypolimnetic aeration employs an airlift device to elevate cold hypolimnetic water to the surface of deep lakes. The water is aerated by atmospheric contact while carbon dioxide and methane are dispelled, and then the water is returned to the hypolimnion. Destratification is not achieved during this procedure (Olem and Flock, 1990).

The objectives of hypolimnetic aeration are threefold:

1. to raise the oxygen content of the hypolimnion,
2. provide an increased habitat and food supply for cold-water fish species, and
3. to decrease the internal P load by establishing aerobic conditions at the sediment-water interface (Cooke et al., 1986).

There is, however, little documentation of its successful use to control nuisance algal blooms.

Negative effects which have been observed are as follows:

1. little increase in hypolimnetic dissolved oxygen if aerator is undersized,
2. metalimnion oxygen depletion preventing the successful establishment of a cold water fishery, and
3. aerators may partially destratify shallow lakes producing severe algal blooms.

According to one manufacturer, Aqua Technique, at a power rate of $0.07 Kw/hour, the average operating cost/KgO_2.day was $0.056 ± 0.02, and the average installed cost/KgO_2.day was $354 ± 216. The approximate cost for Beaver Lake including hardware and installation, would be $50,000 (based on lake volume). Not included in this cost would be electrical trenching and a small building to house the compressor. The estimated cost to operate the system would be $10 to $15 per day (Personal communication).

C. <u>Cause Treatment</u>

Phosphorus is the plant nutrient in New England lakes that most often determines the level of plankton growth. By reducing the phosphorus levels, the cause of the algal problems is attacked. The following methodologies describe ways to reduce the phosphorus levels currently in the lake and entering the lake, and to prevent increases in phosphorus discharged to the lake from future watershed development. These techniques involve both in-lake and watershed controls.

1. Sediment Removal

Dredging of organic lake-bottom sediments is generally implemented for the following purposes (Peterson, 1981): (1) deepening for improved recreational (boating) usage, (2) removal of eutrophying nutrients, (3) removal of toxic substances and, (4) removal and growth reduction of rooted macrophytes. Currently, Beaver Lake has adequate depth for boating and there have been no known discharges of potentially toxic material entering the lake. Macrophyte weed growth is abundant and is considered a nuisance in only some locations. Therefore, the only potential benefit of dredging the ponds would be the removal of nutrients which may be subject to release from the sediments. As discussed previously, Beaver Lake, like most waterbodies, acts as a net phosphorus sink on an annual basis (i.e., more phosphorus is deposited in the sediments from the lake water than is released by the sediments to the lake water). However, removal of phosphorus-enriched sediments could, conditions warranting, further retard the release of sediment phosphorus, thereby resulting in a greater net annual deposition of phosphorus. Additionally, dredging could increase the mean depth of the pond which might permit a greater tolerance to phosphorus loading as depicted by the Dillon/Rigler trophic model.

Unfortunately, adverse sediment characteristics and the physical limitations of standard dredges would severely limit the effectiveness of dredging to improve the trophic status of Beaver Lake.

The depth to which a standard dredge can operate is 15 feet below the lake surface, which would exclude the entire hypolimnetic bottom areas of Beaver Lake from its operation. However, recent advances in hydraulic dredging technology in the last decade has produced more effective cutter bars capable of removing sediment quicker and at deeper depths. The sediment map (Figure IV-6) verifies that most of the bottom areas contain a thick layer of organic detritus. The sediment core analyses (Chapter IX) reveal that there is no significant decrease in phosphorus concentration with sediment depth. Therefore, there is no advantage in decreasing internal phosphorus loading by the removal of the upper sediment layers. The release of sediment phosphorus to the water column would probably be similar because the sediments are only reactive to a shallow depth (approximately 10cm, Snow and DiGiano, 1976).

The Dillon/Rigler and other trophic models demonstrate that a lake's tolerance to phosphorus loading is highly dependent on its mean depth. Increasing the mean depth would result in an improvement of trophic status if the loading remained constant. However, phosphorus tolerance decreases with decreasing flushing rate. Dredging would increase the mean depth which would increase the lake volume and, hence, cause a decrease in flushing rate. These two factors thus counteract each other.

Suitable dredge spoils disposal site(s) of substantial size and location would have to be determined, designed and constructed with protective features such as diking to provide containment and prevent release of nutrients and suspended solids. An outlet structure and sedimentation pond downstream of the disposal area would probably also be necessary. Some treatment of the decant water may be required pending further analysis and characterization of the sediments. No areas proximal to Beaver Lake are topographically amenable to the construction of a disposal area without substantial earth moving and berm construction.

There are several noteworthy adverse effects (Peterson, 1981) associated with sediment removal. Sediment solids are resuspended during dredging activities, thus causing high turbidity in the lake water. Toxicants (unknown) may be liberated to the water column and downstream waterbodies. An algal bloom may be triggered by dredging, due to the release of high concentrations of nutrients in the disturbed sediments and released interstitial water. Lake water oxygen depletion may occur due to increased exposure of the water to bacterial decomposition. The benthic community may be temporarily destroyed. Most of the above concerns are short-term impacts, however, and may be mitigated with a well designed sediment removal plan.

Sediment removal is costly, and the net dredging and disposal cost per unit volume removed varies widely from lake to lake. It is dependent on the equipment (dredges, barges, pumps, etc.), the sediment transport distance to the disposal site, the cost of acquiring and developing the disposal site, and manpower and permit (e.g., Federal Section 404) costs. Peterson (1981) tabulated essential data (including costs) for 64 dredging projects nationwide. Peterson reported a cost range of $0.40 per cubic yard to $23.00 per cubic yard and found that costs from $2.00 to 3.00 (1988 dollars) were common and were considered reasonable for hydraulic dredging. Recent feasibility studies at Kezar Lake (Connor and Martin, 1989) estimated the dredging cost at that lake to be in the range of $1,000,000 to $5,000,000 exclusive of spoils containment design and construction costs.

In order to remove the potential of internal sediment phosphorus loading to Beaver Lake, the benthic areas that are anoxic during the summer months would have to be dredged. In this scenario, all the sediments contained within the 25 foot depth contour would have to be dredged and disposed of. Three sections of Beaver Lake would have to be considered for dredging: the west section (98,248 yd^3), the east section (93,692 yd^3) and the smaller middle section (7,369 yd^3). The total volume of sediment that would have to be removed and disposed of would be 199,308 yd^3. A reasonable cost for hydraulic dredging would be about $600,000. With the spoils containment design and construction and equipment mobilization, cost would run over $1,000,000.

Based on these findings, it is evident that sediment dredging at Beaver Lake as a restorative technique would be costly and of limited value.

2. Phosphorus Inactivation

a. Literature Review

Phosphorus precipitation and sediment inactivation are lake restoration techniques that reduce phosphorus concentration and thereby limit the growth of phytoplankton. Sediment phosphorus inactivation results in longer term lake quality improvement when compared to water column precipitation. Sediment inactivation is particularly useful in accelerating lake improvement in those areas where internal phosphorus release represents a significant contribution to the phosphorus budget (Cooke et al, 1977; Larsen, et al, 1979).

The chemical and physical justification for utilizing aluminum as an inactivant is its ability to form complexes, chelates and insoluble precipitates with phosphorus. Aluminum complexes and polymers are inert to redox changes, are effective in entrapment and removal of inorganic and particulate phosphorus in the water column, and have been shown to have no toxicity at the pH and dose required to improve lake conditions (Cooke and Kennedy, 1981).

Removal of phosphorus by aluminum can occur by precipitation of $AlPO_4$ (Recht and Chassemi, 1970), sorption of phosphates to the surface of aluminum hydroxide polymers or floc (Eisenreich et al., 1977), and/or by entrapment/sedimentation of phosphorus containing particulates by aluminum hydroxide floc. Characteristically, lake water concentrations of inorganic phosphorus are much less than 1 mg P/L (State median=0.011 mg/L) while pH typically ranges from 6.0 to 7.0 units in non-acidified New Hampshire Lakes. Under these conditions, OH^- competes with $PO4^3$ for aluminum ions, (HSU, 1976) favoring the formation of aluminum hydroxide - phosphates.

Dissolved organic phosphates are less effectively removed by inactivation because of the complexity of their molecular structure. Failure to remove dissolved organic phosphorus could be of significance since certain blue-greens can produce phosphatase that removes inorganic phosphorus from any organic phosphates at rates sufficient to support elevated algae populations (Heath and Cooke, 1975). Particulate phosphorus removal effectiveness is controlled by the quantity and quality of the aluminum hydroxide floc. The potential for particulate entrapment should occur in the 6 to 8 pH range.

Once deposited, aluminum hydroxide can provide a continuous control of phosphorus. Kennedy (1978), under experimental conditions, demonstrated that treated sediments are active in retaining phosphorus. Low pH and high phosphorus concentrations in the interstitial water favor the formation of $AlPO_4$. The phosphorus-trapping effectiveness of the floc layer depends on aluminum concentration, pH, the phosphorus concentration and the rate at which phosphorus is supplied to the floc surface.

Within several months of the treatment, the floc consolidates with the sediments and is distinguishable as white-to-brown solid pellets.

A review of the literature provides us with a series of long-term inactivant projects that demonstrate the effectiveness of aluminum hydroxide floc in controlling internal phosphorus loading. Phosphorus inactivation has proven to be highly effective and long-lasting in thermally stratified natural lakes, especially where an adequate dose was applied to the sediments and where nutrient diversion was successfully achieved. Shallow, nonstratified lakes appear to have shorter periods of effectiveness from treatment than stratified lakes and thus have not proven to be ideal candidates for aluminate treatments.

Some of the important lake responses measured following the application of aluminum salts include decreases in lake phosphorus concentration, a sharp decrease in the accumulation of sediment-derived phosphorus to the hypolimnion, an increase in transparency, reduction of phytoplankton populations and a shift in phytoplankton dominance from the more obnoxious Cyanobacteria to other less obnoxious classes.

Some potential negative impacts may be encountered if proper care is not exercised with regard to dose. The potential for toxicity responses is directly related to the acid neutralizing capacity (ANC) and pH of the lake water. Dosage rates, chemical ratios and responding decreases of ANC and pH must be determined under experimental laboratory conditions. Water ANC and pH decrease at a rate dictated by the initial buffering capacity of the water. In low ANC lakes, small doses of aluminum sulfate can exhaust the buffering capacity to a point that causes the pH to decrease below 6. At pH 6 and below, $Al(OH)_2$ and dissolved elemental aluminum (AL^{+3}) become the dominant forms. Both of these species can be toxic to the lake biota. Therefore, sodium aluminate along with aluminum sulfate is required in these lakes to prevent undesirable pH shifts, toxic aluminum concentrations and to generate adequate $Al(OH)_3$ for sediment phosphorus inactivation.

Phosphorus inactivation literature reviews indicate that prior to 1980, 28 surface water bodies had been treated to precipitate or inactivate phosphorus (Cooke and Kennedy, 1981). Within the last eight years, several phosphorus inactivation projects were completed just within New England. However, most of these projects have been completed within the past three years and the final restoration prognosis is yet to be determined. West Twin Lake, Kent, Ohio (Cooke _et al_., 1978) Annabessacook Lake, Winthrop, Maine, (Dominie, 1980), Long Lake, Kitsap County, Washington, (Jacoby _et al_., 1980) and Kezar Lake (Connor and Martin, 1989) are of specific interest. Due to their similarity to Beaver Lake in criteria and/or treatment, a detailed discussion of these cases follows.

1. _West Twin Lake_, Kent, Ohio (Cooke _et al_., 1978).

In 1975, the hypolimnion of West Twin Lake was treated with alum. This treatment was directed primarily at covering the bottom sediments with a layer of aluminum hydroxide to absorb phosphorus molecules released from the sediments. West Twin Lake was classified as a eutropic lake with an area of 34.02 hectares (ha), 4.3 M in mean depth, and a maximum depth of 11.5 M. Liquid alum was added to the 5 M contour, with 26 ha being treated in July of 1975. Dosage rates were based on ANC (102 - 149 mg/L $CaCO_3$) and the amount of aluminum sulfate (liquid alum) which could be added to the point at which pH began to decline and dissolved aluminum began to increase. The application of 91 metric tons was applied in three days at a dose of 27.6 mg Al/L to the hypolimnion. Phosphorus content fell precipitously and remained low through 1978. A small internal phosphorus release, calculated by a phosphorus budget method was not completely controlled, and was thought to be of littoral origin (Cooke and Kennedy, 1980). Cell volume and blue-green algae dominance decreased while transparency increased. There also was some indication of a decrease in microcrustacea diversity.

2. _Annabessacook Lake_, Winthrop, Me. (Dominie, 1980)

Annabessacook Lake has a surface area of 575 ha and a hypolimnetic area of 150 ha. It is a soft water eutrophic lake (20 mg/L as $CaCO_3$), with a pH of 6-7, maximum depth of 14.9 M, and a mean depth of 5.4 M. Dominie calculated that 85% of summer phosphorus increase in the lake was due to internal phosphorus release, presumably from the sediments. The objective of the treatment was to control this phosphorus release. In order to maintain pH to near normal levels, and thereby also prevent the appearance of the toxic levels of dissolved aluminum, a mixture of aluminum sulfate (alum) and sodium aluminate was added to the hypolimnion of the lake in August, 1978. This hypolimnetic aluminum application was designed to accomplish two objectives: first, phosphorus precipitation and entrapment (which is most effective when done in mid to late summer when hypolimnetic phosphorus concentration is greatest) and second, chemical sealing of the sediment by aluminum floc which prevents future phosphorus release. Aluminum application dosages in the top meter of treated water were 25 mg/L for areas 7-10 M deep, and 34 mg/L in areas over 10 M deep. The aluminum application took approximately 18 days, averaging 10 hours per day, and was carried out where depths exceeded 8 M.

The results of aluminum application were at first very encouraging. However, post-monitoring data revealed increases in phosphorus, decreases in transparency and greater blue-green phytoplankton populations. There was little immediate reduction of phosphorus at Annabessacook, as was found at Horseshoe Lake (Peterson et al., 1973) and Medical Lakes (Gasperino and Saltero, 1978) after alum treatment. A large decline in the lake's phosphorus content was observed in September. From the time of treatment in 1977 to one year post treatment there was a 65% reduction in maximum phosphorus mass in the lake.

3. Long Lake, Kitsap County, Washington (Jacoby et al. 1982)

Long Lake is a shallow, unstratified lake, with a mean depth of only 2 M, and a maximum depth of 3.7 M. High pH levels (8 to 10) occur in the summer because of the lake's low buffering capacity (ANC from 10 to 40 mg/L as $CaCO_3$) and the high productivity rates. Internal phosphorus loading in Long Lake was identified as a major eutrophying factor. The sediments in the deeper parts of the lake were shown to be the immediate source of this internal phosphorus loading (Jacoby et al., 1982). In addition, contribution of phosphorus by a dense macrophyte crop was believed to be substantial. A drawdown in the summer of 1979 to control macrophyte growth was unsuccessful, with recolonization approaching pre-drawdown levels by the summer of 1981.

In September, 1980, alum was applied to Long Lake at a rate of 5.5 mg Al^{3+}/L to provide a barrier to phosphorus release from the sediments. The alum floc remained well incorporated in the surficial sediments and served as an effective barrier to the vertical diffusion of soluble reactive phosphorus. Phosphorus control continued 2 years after treatment, in spite of a full macrophyte recovery. The alum may have continued to be effective by inactivating or complexing newly deposited phosphorus from macrophytes. One detrimental side effect was noted. The improved water column clarity resulted in increased density and distribution of Potamogeton praelongus and P. pectinatus in the deeper 3 M area of the lake, impacting boating and fishing activities. These areas of the lake previously had little macrophyte growth.

4. Kear Lake, North Sutton, New Hampshire (Connor and Martin, 1989):

Aluminum sulfate and sodium aluminate were utilized as sediment phosphorus inactivants to improve the water quality of a northeastern eutrophic lake. A four-year monitoring program provided an extensive lake-database utilized to evaluate the short-and long-term effectiveness of sediment phosphorus inactivation as a lake restoration technique. An immediate impact of treatment was a reduction in hypolimnetic BOD and dissolved oxygen deficit, lower chlorophyll-a and phosphorus concentrations, improved transparency, and the elimination of obnoxious blue-green phytoplankton blooms. For two to three years after treatment, these parameters continued to exhibit both less variability and improved values over the pre-treatment conditions. The improved water quality conditions warranted an upgrade of the lake trophic status from eutrophic to mesotrophic. Eight years after treatment, transparency values are still acceptable for recreation, (ranging from a minimum of 2.2 m to a maximum of 3.4 M during the 1992 season) while productivity was considered to be moderate (1992 chlorophyll range 4.2-8.2 ug/L) and internal phosphorus loading was considered reasonable. A major benefit is an increase in the average attendance at the lake's State Park by almost 2,000 people per summer.

b. Environmental Effects of Phosphorus Inactivation Treatments

In order to assess the long-term environmental effects of phosphorus inactivation by treatment with aluminum, future research must be conducted to evaluate the effects on species diversity, fish populations, bioaccumulation of aluminum, potential impacts on human health, and related uses of lake water.

At this time, there is already some direct laboratory and field evidence concerning the short and long term effects of aluminum on aquatic biota and aquatic communities. Cooke, Heath, Kennedy and McComas (1982) observed few negative effects as a result of hypolimnetic alum treatment of West Twin lake (5 years post-treatment) and Dollar Lake (6 years post-treatment), as well as Connor and Martin (1986), who observed few negative effects with an application of aluminum sulfate and sodium aluminate. Specific conductance, ANC, pH, sulfate, and dissolved aluminum were monitored regularly and no remarkable or excessive changes were noted. Residual dissolved aluminum (RDA), ANC, and pH all recovered rapidly after the treatment was completed. Transparency increased after aluminum application and remained high. These investigations report significant changes in species composition of phytoplankton and zooplankton following aluminum. It apppears that changes in this diversity may be attributable to increased clarity and decreased nutrient content, rather than toxicity. The decline in planktonic microcrustacean diversity was apparently not due to aluminum toxicity in the water column, but to changes in the type of algae cells present, changes in pH, or perhaps RDA changes in the interstitial waters where resting stages of microcrustceans might be found. Greatly increased transparency may enhance fish predation on zooplankton and contribute to reduced diversity.

Jacoby, Welch, and Michaud (1982) also reported that increased water column clarity in alum treated Long Lake, Washington, resulted in an increase in the biomass of macrophytes in the deeper (3 M) area of the lake. Previously, this area had been relatively free of noticeable macrophytes, but had a dense algal biomass which decreased significantly after treatemnt.

However, despite the overall improvement in lake quality and the lack of blue-green algae blooms, recreationists still complained of the impact of the macrophytes on boating and fishing activities on the lake.

Hypolimnetic aluminum sulfate treatment of Bullhead Lake, reported by Narf (1981), indicated that a reduction in phosphorus concentrations apparently shifted the lake's microflora from a blue-green to a green dominant community.

Narf (1978) also reports an extensive evaluation of aluminum sulfate treatments on benthic insect communities. His study showed that the benthic insects suffered no toxic effects and generally increased the first year following the aluminum sulfate application. The presence of the aluminum flocculus did not appear to influence the species composition or numbers. Snake Lake, with one of the higher applied dosages of aluminum, produced the largest populations of benthic insects during the two years following treatment. At Long and Pickerel Lakes, the population shifts were less dramatic, but indicated no decline immediately after treatment, or for a number of years following.

The use of aluminum apparently enhances the lake quality for benthic organisms for a time period dependent on lake conditions. Narf also reported that benthic insect-burrowing activities may greatly contribute to phosphorus recycling of lake sediments. He observed that the apparent secondary toxicity in laboratory bioassays, using 93 and 140 g Al_3/M^2, can be explained by the probable change of the flocculus to a more cohesive precipitate layer. This was less pervious to biological and chemical diffusion, thus suffocating the insects. Dominie (pers. comm.) also noted the same phenomenon in his bioassay procedure.

Several investigators have reported an absence of negative effects on fish (Kennedy and Cooke, 1974; Buergel and Soltero, 1983; Connor and Martin, 1986) after a lake treatment. Everhart and Freeman (1973) used a constant flow bioassay to test toxicity to rainbow trout. At 52 ug Al/L, there were no obvious effects on growth or behavior, leading Kennedy and Cooke to adopt this value as an upper RDA limit for lake treatment. Peterson et al. (1974, 1976), using static bioassay, reported that Chinook salmon survived an RDA of about 20 ug Al/L. Higher concentrations were not tested. Buergel and Soltero (1983) studied the possibility of bioaccumulation in stocked rainbow trout after a whole lake application of alum to Medical Lake, Washington. This study was particularly pertinent because these trout and their prey were dependent upon habitat potentially higher in available aluminum than neighboring habitats. Trout tissue, plankton, and water were analyzed for total aluminum concentrations. Statistical comparisons revealed few overall differences in the level of aluminum in alum exposed and non-exposed fish, although significant differences existed among tissues within a given treatment and age class. Aluminum levels in plankton were approximately 10 times higher (dry weight comparison) than encountered in trout tissue, and may help to account for levels found in trout. The lack of aluminum in the muscle tissue suggests diminished vascularization or no metabolic means of storing aluminum. Further research is needed to study the impacts and fate of aluminum in tissues.

The modern phenomenon of acid precipitation, and the possible resultant mobilization of aluminum to the aquatic environment, warrants further research to study the potential biological impact of aluminum. Also, further study should be undertaken concerning the interactions of aluminum and the inherent environmental complexing agents of chelators and the subsequent toxicity potential. From the research performed thus far on the use of aluminum salts for phosphorus inactivation, it appears that increases in aluminum caused by these treatments do not deleteriously affect species diversity of fish populations, and do not lead to bioaccumulation of aluminum in the fish.

c. Cost Comparisons for Aluminum Salts Application

A comparison of labor, equipment and chemical costs between seven phosphorus inactivation projects on seven different lakes is summarized in Table XI-1. With the exception of Sluice Pond, the cost effectiveness of phosphorus inactivation has increased since earlier (late 1970) treatments. Although the cost of aluminum has increased, the chemical application techniques have become more efficient and less labor intensive.

The cost effectiveness of aluminum salts injection can best be demonstrated by comparing labor, chemical, and equipment costs. Table XI-1 demonstrates the aluminum salts application effectiveness of the modified harvester (Connor and Smith, 1986), an older barge system, and a modified treatment barge recently developed by Sweetwater Technology.

A comparison of the person-days worked per hectare revealed that the harvester was much more effective than the barge method utilized at Annabessacook Lake. The modified harvester utilized at Kezar, Morey, and Cochnewagon Lakes saved an average of 0.63 person-days/ha when compared to the barge method utilized at Annabessacook Lake. However, it appears the cost-effectiveness of aluminum salts injection decreased with lake areas under 20 hectares. A computerized chemical distribution system developed by Sweetwater Technology has increased the efficiency of chemical application, and a portable LORAN navigational system has increased the path accuracy to 9 inch/0.5 mi (225 cm/0.8km). This one-person operation is capable of applying up to 35,000 gallons (133,000L) of liquids per day. These improvements increase the efficiency and economical application of aluminum salts. The computerized barge saved an average 0.43 person-days/ha and an average of $512.00 per hectare over both the old barge and modified harvester systems.

TABLE XI-1

A Comparison of Aluminum Dose, Cost, and Productivity Data for Phosphorus Inactivation*

Lake	Year Treated	Area Treated (ha)	Aluminum Dose	Cost for, Chemicals Labor and Equipment	Manday/ha	Cost/ha
Medical Lake, Washington[1]	1977	60	8.0 g Al/m^3 Aluminum Sulfate	$132,093	No data	$2,202
Annabessacook Lake, Maine[1]	1978	121	25 g Al/m^3 Aluminum Sulfate Sodium Aluminate	$234,000	1.12	$1,934
Kezar Lake New Hampshire[2]	1984	48	40 g Al/m^3 Aluminum Sulfate Sodium Aluminate	$65,604	0.50	$1,367
Lake Morey, Vermont[2]	1986	133	45 g Al/m^2 Aluminum Sulfate Sodium Aluminate	$165,640	0.57	$1,245
Cochnewagon Lake, Maine[2]	1986	97	18 g Al/m^3 Aluminum Sulfate Sodium Aluminate	$81,840	0.41	$844
Sluice Pond, Massachusetts[2]	1987	6	20 g Al/m^2 Aluminum Sulfate Sodium Aluminate	$13,196	0.67	$2,199
3 Mile Pond, Maine[3]	1988	266	20 g Al/m^2 Aluminum Sulfate Sodium Aluminate	$170,240	0.06	$640

*Data from Connor and Smith, 1986; Gerald Smith, Aquatic Control Technology; and Richard H. Lepley, Sweetwater Technology Corp.

[1]old barge system

[2]modified harvester

[3]new barge system

d. Application Feasibility for Sediment Phosphorus Inactivation

The simultaneous application of two aluminum salts with either a specially modified aquatic weed harvester (Connor and Smith, 1986) or the new barge system (Sweetwater Technology) has proven to be an efficient method of treating stratified lakes for both reduction of hypolimnetic phosphorus and inactivation of sediment phosphorus (Connor and Martin, 1989).

Beaver Lake has adequate accessibility for launching the necessary equipment and for tanker truck dispersion of chemicals to the distribution mechanism. Possible access points on the lake to be utilized for launching and chemical dispersion include the public launch, Comeau's Beach and Beaver Lake Park. Several locations on North Shore Road and Pond Road could be utilizied as chemical refill stations so the barge has less distance to travel for refills. Before cost estimates can be made, three important factors must be determined. Each of these factors will determine the ultimate success of the project in sediment phosphorus inactivation and will determine the ultimate project cost.

1. The treatment area of the lake must be determined by defining the areas of the lake that contribute to internal phosphorus loading. In some cases this area may be confined to the stratified anoxic hypolimnetic area of a lake. A more practical approach involves mapping the benthic sediments to their type and depth. A rich organic sediment will yield a greater phosphorus load to the lake than an inorganic sandy substrate. Over 70% of the Kezar Lake sediment was treated with aluminum salts. An organic sediment map was prepared for Beaver Lake (Figure IV-6). The sediment-muck area map shows that much of the Beaver Lake benthic area is covered with a rich organic substrate that is considered a prime source of internal phosphorus loading.

   The area to be treated with aluminum salts was selected by determining the organic sediment distribution on the lake's bottom. The lake bottom area with an organic layer greater than or equal to the five foot sediment contour was selected for treatment. This area represented 67 percent of Beaver Lake's benthic area.

2. Since New Hampshire lakes are low in ANC and considered soft water, only small amounts of aluminum sulfate can be added before the pH falls below 6.0. In these lakes, sodium aluminate must also be added with aluminum sulfate. Sodium aluminate, which increases the pH of an aqueous solution, is utilized to maintain a pH above 6.0. The ratio of aluminum sulfate to sodium aluminate must be empirically determined. These ratios are determined by conducting jar tests utilizing water from the lake to be treated. Several tests including pH and aluminum are conducted to determine the proper ratio to be utilized during the treatment.

3. The total aluminum dosage must be calculated for the lake. A basis for aluminum dose now exists. The Kennedy procedure (Kennedy & Cooke, 1980) is based on the assumption that as much aluminum as possible should be added, up to the pH where significant amounts of dissolved aluminum appear, since the goal is long term lake improvement. From our past experience with sediment phosphorus inactivation, we will assume an aluminum dose of 40 g Al/m^3.

The estimated cost for sediment phosphorus inactivation of 35 ha for Beaver Lake will range from $25,000 to $53,000. Figures are dependent upon the application methodology and include equipment, labor and chemical cost.

There is no apparent significant social impact of the phosphorus inactivation treatments of lakes. There will be minimal disruptions of the use of the lake and no restrictions placed on the subsequent water use. There are no disposal problems associated with the procedure, and no adverse impacts on docks, marinas, or other water structures.

3. Dilution and Flushing

Lake waters that exhibit low concentrations of phosphorus are unlikely to maintain algal blooms. While ideally it is more feasible to divert or treat phosphorus rich waters before they empty into a lake, it is possible to lower the concentration of phosphorus within the lake and to flush out algal cells by adding sufficient quantities of phosphorus-poor water from some additional source. High amounts of additional water can also be used to flush algae cells from the lake faster than they grow.

Lakes with low flushing rates are poor candidates because in-lake concentration could increase unless dilution water is essentially devoid of phosphorus and sufficient water is added to gain a high flushing rate. Internal phosphorus release could further complicate the effect.

Flushing can control algal biomass by cell washout. The flushing rate must be near the cell growth rate to be effective. Flushing rates of 10-15 percent of the lake volume per day are believed to be sufficient (Cooke et al. 1986). Since Beaver Lake only flushes 5.1 times per year, this may not be a feasible means of restoration. Few case histories that document the effectiveness of dilution and flushing exist. The greatest problem is locating a dilution source that is low in phosphorus. Cooke et al. (1986) describe one successful case where low-phosphate Columbia River water was diverted through Moses Lake, Washington. Water exchange rates of 10 to 20 percent/day were achieved, and transparency and productivity dramatically improved.

Outlet structures must be capable of handling the added discharge, and increased volume released downstream may have water quality impacts to lakes and ponds located downstream.

Costs will vary greatly from lake to lake. Costs depend on the need for pumps, engineering costs, outlet structure preparation and the proximity of water with less phosphorus.

4. Sediment Oxidation

RIPLOX, a highly experimental procedure (Ripl, 1976) has only a few existing case histories. The objective of this procedure is to decrease phosphorus release from sediments, in much the same way as with phosphorus inactivation. Addition of ferric chloride to the sediments enhances phosphorus precipitation. Lime is then added to adjust the sediment pH for optimum denitrification. The final step promotes the oxidation of organic matter and denitrification through a calcium nitrate injection of the top 10 inches of sediment.

Lake Lillesjon, a 10.5 acre Swedish lake with a mean depth of 6.6 feet was treated at a cost of $112,000. Only $7,000 of the total cost was for chemicals while the remaining costs were for equipment development and research (Olem and Flock, 1990).

Beaver Lake sediment analyses (Chapter VIII) have revealed high iron concentrations distributed throughout the sediment core. Sediment iron concentrations of this magnitude may limit the use of Riplox as a restorative technique.

5. Biomanipulation

Another highly experimental restoration technique utilizes zooplankton grazing for reducing plankton populations. Shapiro et al. (1975) defined "biomanipulation" as the procedure of enhancing grazer control of algae by eliminating planktivorous fish through the use of fish poisons or fish winterkill, or by the addition of enough predators to limit planktivore consumption of beneficial zooplankton. With such manipulations, it may be possible to improve a lake without an expensive nutrient diversion program. The simple addition of predatory fish, however, may not be sufficient to produce a reasonable control of plankton. The type of plankton available as a food source to the herbivores and planktivores will have a direct effect on the project's outcome.

One possible difficulty in the biomanipulation method is that toxicity induced fish kills from plankton have been documented at several waterbodies throughout the world. Certain species of blue-green plankton release endotoxins upon cell lysis. When toxic species of plankton are dominant, severe disruptions in the aquatic food chain are probable.

Water-bodies which have depressed hypolimnetic oxygen concentrations usually are poor choices for biomanipulation as a restoration technique. Anoxic hypolimnions eliminate a particular refuge from sight-feeding planktivores and this enhances zooplankton mortality.

Costs for biomanipulation are not readily available. Fish poisons are expensive and cleanups are costly. The cost of restructuring a food web through enhancement of a predatory fish population will be specific to each (Olem and Flock, 1990). In the case of Beaver Lake, biomanipulation would have to be supplemented by the additional cost of hypolimnetic aeration.

D. Watershed Management

1. Introduction

The implementation of proper watershed management techniques within the Beaver Lake watershed will mitigate the decline in water quality throughout the study area. Continued population growth and the associated growth in residential and commercial development, the continuing pressures from seasonal home development and conversion, and an increase in recreational use, combine to place a burden on the surface water resources within the region. Watershed management techniques designed to reduce this pressure include a variety of land use, land management and wetlands management techniques.

Each of these groups of management techniques plays a major role in the preservation of lake quality levels within the watershed. The existing condition of the lake, and the nutrient supply sources identified by the study clearly point out the need to eliminate or reduce those factors that might contribute to the decline in lake quality. While it is not possible to place specific values on each management practice in terms of potential reduced loads, it is clear that these practices, taken individually or in combination, will help to ensure that future development will be conducted in a manner that does not accelerate the decline in water quality.

2. Phosphorus Attenuation Utilizing Wetland Management

Most studies examining water quality changes in temperate wetlands found distinct seasonal variations in wetland attenuation of phosphorus. Although these variations were generally marked by minimum attenuation or even release of phosphorus during the fall and spring high flows, the specific conditions at any particular site may alter this seasonal pattern. Several studies indicated that wetlands were net accumulators of phosphorus on an annual basis, and may have maximum seasonal removal efficiencies from 80 to 98 percent during the summer growing season. This seasonal attenuation of phosphorus by the wetlands may be significant inasmuch as it may delay the entry of nutrients into downstream water bodies until the fall, winter, or in some cases, spring, when their impact may be less severe (Lee et. al., 1975).

Bentley (1969) studied four wetlands in Wisconsin and estimated that on a long-term basis, they were neither nutrient sources nor sinks, but that the marshes tended to accumulate nutrients during the growing season and release them during spring runoff. However, even during periods of active photosynthesis, the wetlands were not a barrier to nutrient transport.

A study on the Chadwick Meadows wetland in North Sutton, NH, revealed that newly created wetland areas may act for many years as a phosphorus source, rather than a phosphorus sink. Flooded in 1983, Chadwick Meadows has yet to provide the theorized phosphorus reduction in tributary loading to Kezar Lake (Connor and Martin, 1986).

Richardson (1988) examined the ecological value of wetlands in terms of the ability to filter materials, transform nutrients, or function as sources or sinks. Macrophytes are mainly responsible for the recycling of phosphorus through root uptake from the soil; plants are the source of phosphorus for the water rather than the reverse. Richardson concluded that wetlands are incorrectly depicted as sinks when, in fact, they should be recognized as transformers. Wetlands with organic soils do not retain phosphorus as efficiently as forested systems and are often a source of nutrients rather than a sink for them.

In addition to incorporating nutrients into plant tissue, marshes also serve to settle out a large portion of the suspended particulate materials and to remove nitrogen through dentrification reactions. On the other hand, the periodic occurrence of anaerobic conditions increases the possibility for discharge of ammonia and soluble inorganic phosphorus, particularly in wetlands subject to pulses of high discharge from runoff.

a. Pollutant Removal by Utilizing Wet Ponds (From Schueler, 1987)

The capability of wet ponds to remove pollutants borne in urban runoff has been demonstrated in local and national field studies (US EPA, 1983; MWCOG, 1983b). These studies found pollutant removal to be variable from storm to storm, but generally high over the long-term, for well designed and maintained ponds. The degree of pollutant removal achieved by a pond is a function of the size and design of the permanent pool and the characteristics of individual urban pollutants.

1. Pollutant Removal Mechanisms in Wet Ponds

i. Sedimentation

In theory, the incoming storm runoff displaces "old water" out of the pond and is then stored until the next storm. Suspended pollutants settle out from the water column to the pond sediments. Moreover, the permanent pool acts as a barrier to resuspension of deposited materials, improving removal performance over that achieved by dry ponds. The greatest initial settling often occurs near the inlet of the pond, where the velocity of the incoming runoff is dissipated by the still waters of the permanent pool. Settling in ponds during quiescent conditions can be modeled assuming Stokes Law Type I Sedimentation. Coarser materials are deposited first, followed by progressively finer-sized fractions. In practice, sedimentation is an effective pollutant removal mechanism unless short-circuiting occurs (i.e., incoming runoff passes through the pond without displacing the old water), or the volume of incoming runoff is greater than the volume of the permanent pool (in which case some portion of the runoff passes through the pond unmodified). As a result of these factors, pollutant removal rates often decline during larger storms in smaller ponds.

ii. Biological Uptake

A unique feature of wet ponds is the presence of aquatic plants and algae that can remove significant amounts of soluble nutrients from the water column. Since soluble nutrients have minimal settling velocities, biological uptake represents an important removal pathway. In short, the plants convert the soluble nutrients into biomass which in turn can settle to the pond sediments. Once nutrients and organic materials are trapped in the sediments, they may be consumed by bacteria and removed from the system.

2. Estimates of Wet Pond Removal Efficiency

The pollutant removal capability of two wet pond facilities were evaluated during the Washington, D.C. area NURP study (MWCOG, 1983b; OWML, 1983). The wet ponds were found to be effective in removing particulate pollutants, with long-term average removal for the two ponds of 54% for sediment, 30% for chemical oxygen demand, 51% for zinc, 65% for lead, and approximately 20% for both organic nitrogen and phosphorus. In general, the removal of particulate pollutants in the wet ponds was very similar to that observed in extended detention ponds. Removal of organic materials was slightly lower in wet ponds in comparison to extended detention ponds, perhaps as a result of export of biomass and/or detritus from the ponds. The wet ponds were more effective in removing soluble nutrients with long-term removal of 60% of the nitrate and over 80% of the soluble phosphorus recorded during the course of the study. Uptake by algae and aquatic plants was apparently responsible for the removal.

Wet ponds monitored at other NURP projects (Tri-County RPC, 1983; US EPA, 1983a; Driscoll, 1983) followed the same pattern of pollutant removal observed in the Washington, D.C. area, with high sediment and trace metal removal, moderate removal of organic nutrients and COD, and apparently high removal of soluble nutrients. The absolute level of pollutant removal was found to be primarily a function of the ratio of pond volume to watershed size (US EPA, 1986b; Driscoll, 1983). Relatively undersized wet ponds had low and occasionally negative removal efficiencies, while moderate to large-sized ponds had correspondingly higher removal rates.

3. Design Tips for Enhancing Pollutant Removal

Pool Volume

The size of the permanent pool in relation to the contributing watershed is perhaps the single greatest factor influencing pollutant removal in wet ponds. Larger ponds remove pollutants better than smaller ones, and in general, "bigger is better". However, after a certain threshold size is reached, further removal by sedimentation is negligible. Also, an upper limit on pond size may be imposed by construction costs and site constraints. A number of wet pond sizing rules have been proposed to optimize pollutant removal. These alternative rules variously specify that the minimum volume of the permanent pool be equivalent to:

SIZING
RULE 1: One-half inch of runoff distributed over the contributing watershed area (Montgomery County DEP, 1984).

SIZING

RULE 2: One-half inch of runoff distributed over the impervious portion of the contributing watershed (Md WRA, 1986).

SIZING

RULE 3: Volume of permanent pool equivalent to a variable depth of runoff distributed over the contributing watershed, depending on land use (NVPDC, 1987; Fairfax County DEM, 1980).

4. Design Criteria

Short-circuiting is a frequently cited problem in wet pond design, whereby the incoming water flows directly through to the outlet. Short-circuiting can be minimized by maximizing the distance between the pond inlet and outlet. The accepted minimum length to width ratios are 3:1 or greater. However, the addition of baffles can be placed within the pond to absorb the flow energy and distribute the solids load.

Since much of the pollutant removal in a wet pond is accomplished by gradual settling, pond depth is an important design aspect. Many modeling analyses indicate that shallow ponds have higher removal efficiencies than deeper ones. However, ponds less than two feet deep are prone to resuspension problems from wind action. For design purposes, an average pond depth of 3 to 6 feet should be optional (Schueler, 1987).

The depth of the permanent pool should be variable. Shallow depths near the pond inlet and around the perimeter should be established to encourage aquatic vegetation and to concentrate sediment deposition.

The establishment of aquatic vegetation around the perimeter of the pond enhances pollutant removal, protects the shoreline from erosion, and can trap incoming sediment. While most emergent plants withdraw nutrients from the sediments rather than the water column, associated algae which are attached to the plants, or grown nearby on shallow sediments are capable of soluble nutrient removal. Shallow, organic-rich waters provide an ideal environment for bacteria or other microorganisms that reduce organic matter and nutrients.

The slopes around the pond should be gradual to prevent bank erosion and to encourage aquatic macrophyte growth.

The stream channel below the pond outlet should be lined with large stone riprap to prevent scouring and have a slope close to 0.5% (MNCPPC, 1984).

5. Management of the Manter Brook Subwatershed

Manter Brook contributes the greatest phosphorus load of all the inflowing tributaries, representing 68 percent of the tributary phosphorus load. Because of the significance of this loading source, Manter Brook is a key component of the budget that can be reduced.

Currently, a small ponded area (1.3 ac) exists above the Manter Brook inlet to Beaver Lake. The pond as constructed probably has little ability to retain suspended solids and materials. The combination of hydrologic diversion and biological remediation could convert this area into a sediment and phosphorus retention basin.

Figure XI-1 is a schematic representation that would result in the enlargement of certain areas of the pond, the seeding of aquatic macrophytes that have shown good phosphate uptake capabilities, and the diversion of flow patterns through the planted areas to reduce the flow of water and the load of sediment and phosphorus to the lake.

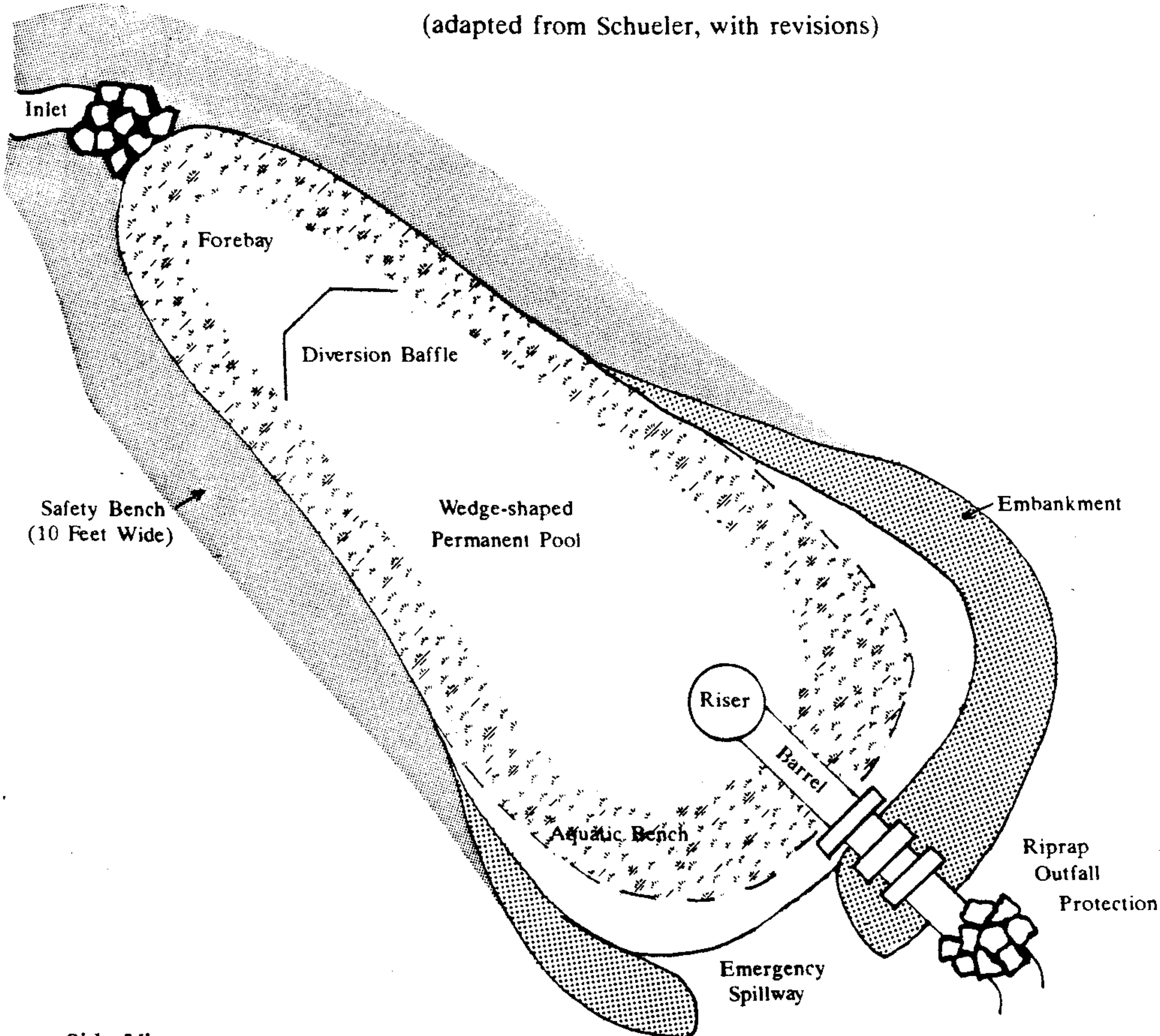
Wet ponds, also known as retention ponds, are an extremely effective water quality BMP. If properly sized and maintained, wet ponds can achieve a high removal rate of sediment, BOD, organic nutrients and trace metals. Biological processes within the pond also remove soluble nutrients (nitrate and ortho phosphate) that contribute to nutrient enrichment (eutrophication). Wet ponds are most cost-effective in larger, more intensively developed sites. Positive impacts of wet ponds include: creation of local wildlife habitat, higher property values, recreation, and landscape amenities. Negative impacts include: possible upstream and downstream habitat degradation, potential safety hazards, occasional nuisance problems (e.g., odor, algae, and debris), and the eventual need for costly sediment removal (Schueler, 1987).

Wet ponds can be utilized as a multi-purpose BMP. They can function as stormwater management, pollutant removal and habitat improvement.

Schematic of a Wet Pond

(adapted from Schueler, with revisions)

Top View



Side View

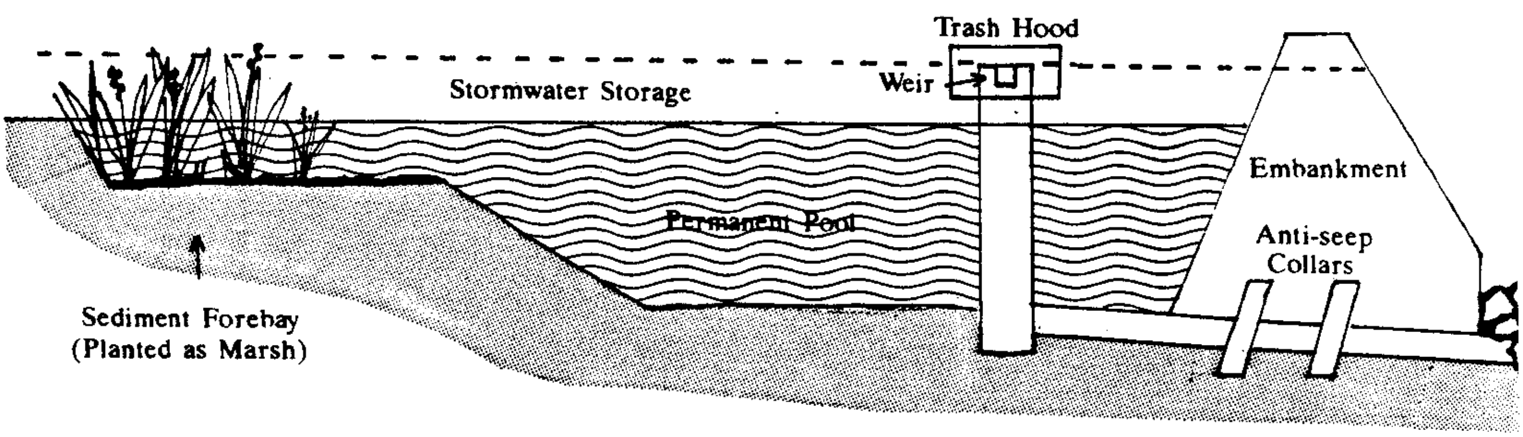


Figure XI-1

6. Wet Pond Construction Costs

Wet pond construction costs are largely determined by the total storage volume. Costs can be significantly lowered if natural depressions and topography are creatively used. The Manter inlet to Beaver Lake includes approximately 1.3 acres of ponded water created by an artificial dam. This ponded area is surrounded by over two acres of town-owned property.

Currently, the estimated storage volume of the ponded area is 7000 cf, assuming the average depth is three feet. A wet pond with a permanent pool of 7000cf would have to have an additional stormwater volume of 1400cf.

A planning estimate of the base construction cost for a wet pond of less than 100,000 cf of storage can be approximated by using the MWCOG equation (Wiegand et al., 1986):

$C=6.1\ V_S\ 0.75$

Where C=construction cost (1985x10%)

V_S=volume of storage (cubic feet)

It would cost approximately $7,500 to reconstruct certain areas of the pond, enlarging the storage capacity and sloping the banks. Adding at least one or more baffles, installing a riser outlet and ripraping would also be part of the cost. Planting the proper aquatic macrophytes would cost an additional $1,000 for a total cost of approximately $9,000.

Any work completed by the City Public Works Department utilizing city equipment would dramatically lower the total cost of this phase of the project. The use of city employees and equipment to construct this wet pond can be utilized as local match for Phase II.

b. Pollutant Removal from Stormwater Runoff.

Although the shoreline of Beaver Lake was sewered, no provisions were made to collect stormwater runoff to the lake. Dennis (1986) estimated that the four largest runoff events accounted for 65 percent of the total phosphorus export to a Maine Lake, and a single storm event contributed almost 50 percent of the phosphorus load to that same lake.

As was stated in Chapter 8, many studies have shown that much of the phosphorus load can occur during the first centimeter of rainfall. A study conducted in a Maine watershed estimated that 69 percent of the phosphorus export occurred during the first centimeter of runoff while 90 percent and 97 percent occurred during the first two cm and three cm respectively.

Best management practices designed for stormwater runoff to Beaver Lake should focus on erosion and sediment control and water quality control. Figure XI-2 shows that at least eleven stormwater culverts discharge directly into Beaver Lake, and at least five dishcarge into monitored tributaries.

Stormwater culverts that drain directly into Beaver Lake should be eliminated in favor of a three tier approach of flow reduction, particle settlement and infiltration. One means of achieving these goals is to replace stormwater culverts with a rock riprap channel that grades into either a vegetated filter strip or vegetated swale.

1. Riprap Construction and Associated Costs

Rock riprap is a permanent, erosion-resistant layer of loose, well-graded stones, having sufficient size, gradation, and thickness to provide stability and protection to underlying materials. The key capacity of the riprap channel at Beaver Lake would be to slow the velocity of concentrated runoff which in turn increases the potential for infiltration as the stormwater enters the swale.

A well graded mixture of rock sizes should be used for riprap rather than rocks of a uniform size. Properly sized bedding or geotextile fabric is needed to prevent erosion or undermining of the natural underlying material.

Stone used for riprap must be durable so premature decomposition from freezing, thawing, wetting, or drying does not occur. Granite (broken into pieces) usually is the stone of choice.

The thickness of a layer of riprap shall be 1.5 times the maximum stone equivalent diameter. A filter will be required between the rock riprap layer and the soil base beneath the rock to prevent the base soil from moving through the void spaces in the rock.

The cost of constructing a riprap channel or infiltration trench varies depending on the area of the trench, the availability of stone fill and if the public works department does the construction work.

Constructing a 100 foot long, 6 foot deep, and 6 foot wide trench would create the following component costs:

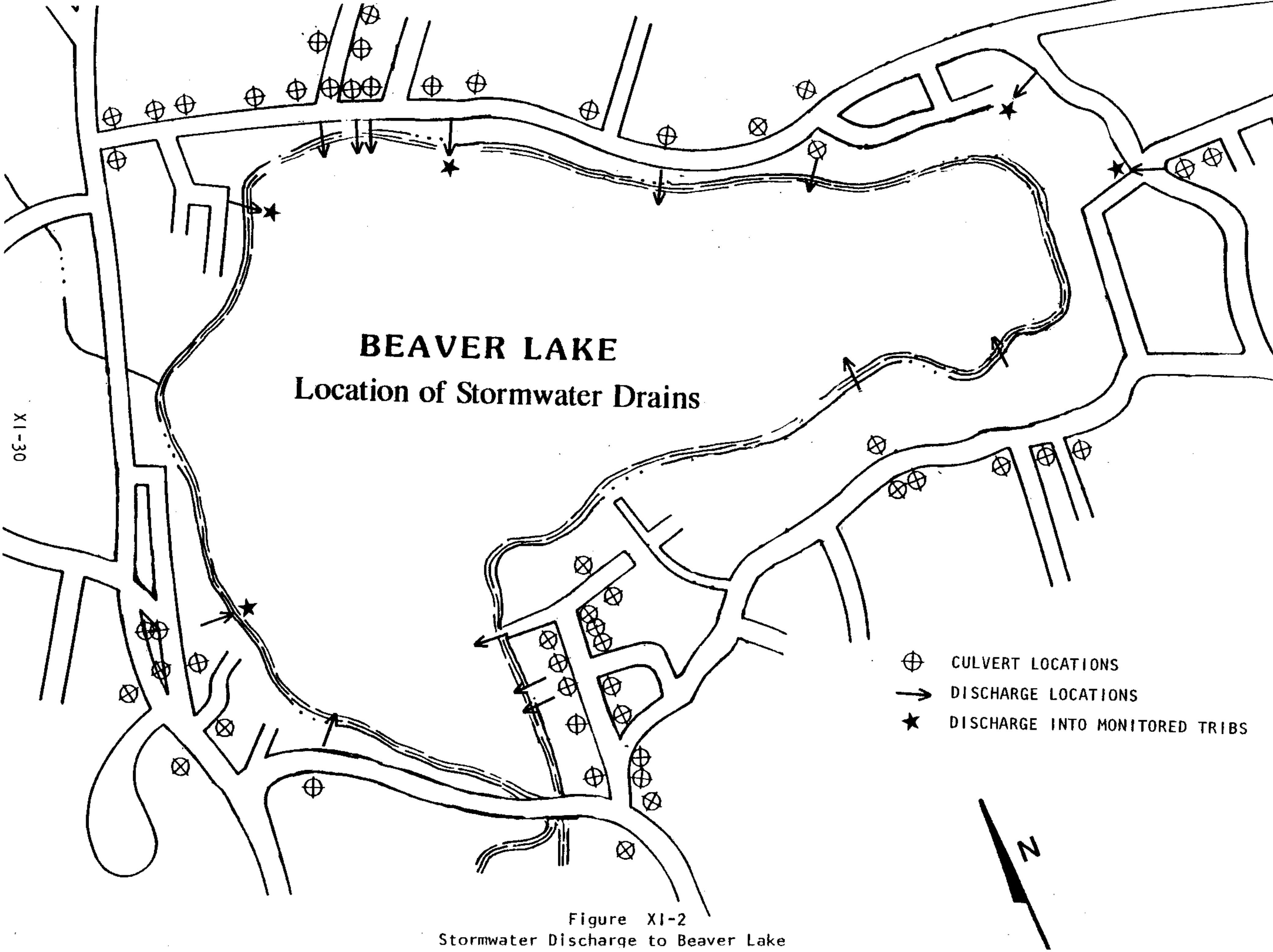


Figure XI-2
Stormwater Discharge to Beaver Lake

Excavation:(If contracted) (100ft) (6ft) (6ft)/27=133yd^3

at(2.82 yd^3) (.10)=<u>$415</u>

Stone fill: 133yd^3 at $25/yd^3=<u>$3,325</u>

Filter cloth: 2(6x6) + 2(100x6)

approximately 2500 9=278 yd^2

(278 yd^2) (2.7) (10)=<u>$825</u>

Total cost=<u>$4565.00</u>

At least three riprap trenches would have to be constructed for those direct stormwater drainage systems.

2. Vegetated Swales and Associated Costs

Pollutants are removed by the filtering action of the grass, deposition in low velocity areas, or by infiltration into the subsoil. Schueler (1987) describes the minimum design considerations that must be incorporated into swale design if moderate particulate removal is to occur:

1. Swale slopes need to be graded as close to zero as drainage will permit. Side slopes of the swale should be no greater than 3:1(h:v).
2. A dense cover of a water tolerant, erosion resistant grass, like reed grass, must be established.
3. Underlying soils need to have high permeability (fc> 0.5 in/h). The swale should be tilled before grass cover to restore infiltration capacity.
4. Check dams can be installed in swales to promote additional infiltration. Railroad ties should be sunk halfway into the swale and stone placed on the downstream side of the tie to prevent a scour hole.

The swale should be designed to receive a flow of 1.0 foot/second with a minimum length of 100 feet. The cross section may be parabolic, triangular or trapezoidal.

The cost for a 15 foot wide, 3:1 sideslope swale would range from $4.50 a linear foot with seeding and straw mulching to $8.25 a linear foot with seeding and net achoring. For a 100 ft swale the cost would range from $450 to $825.

The proposed model of the Beaver Lake BMP for stormwater treatment is presented in Figure XI-3.

3. Shoreland and Watershed Protection

a. Master Plan

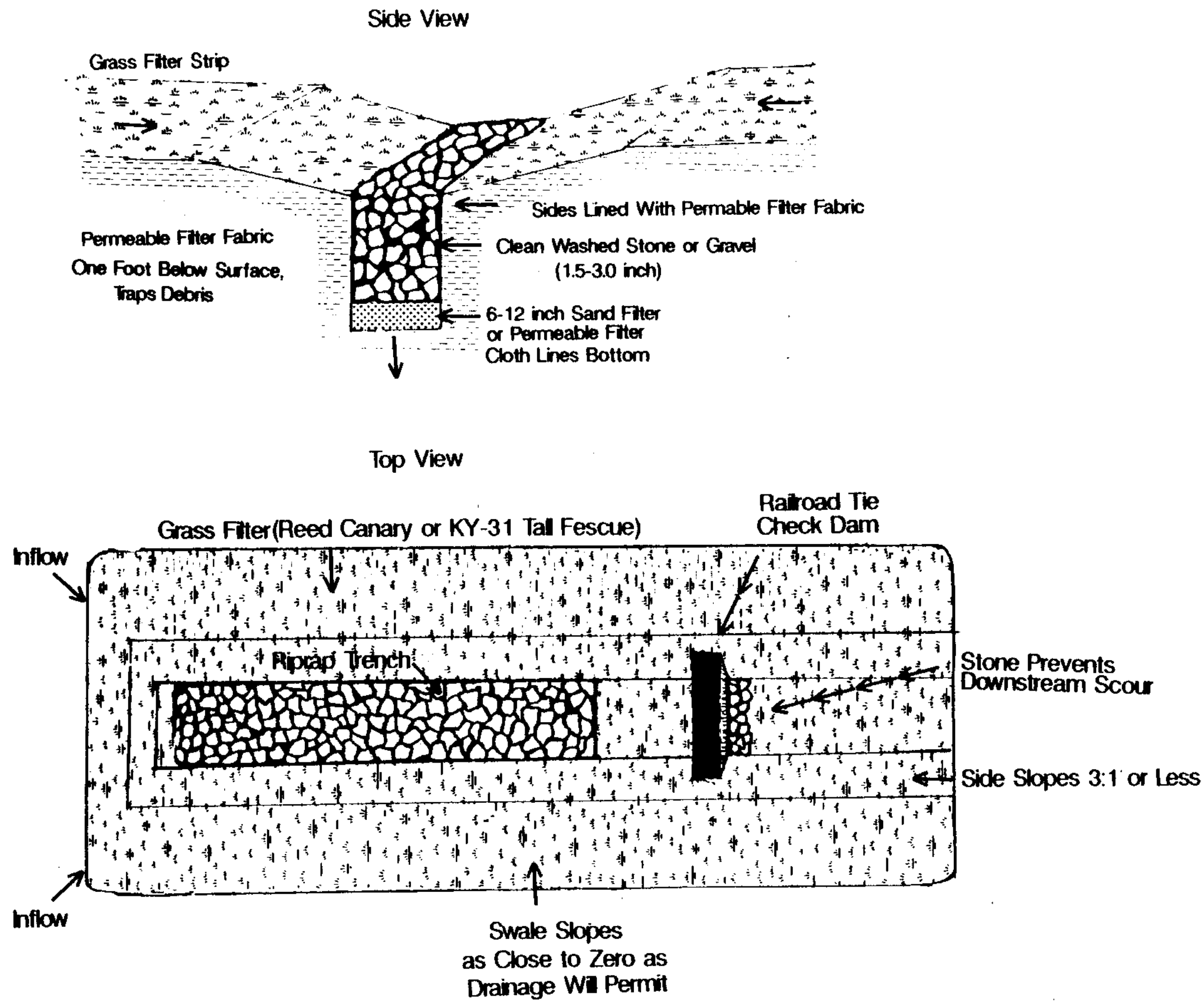
The Town of Derry has a master plan that was revised in 1991. These plans and the planning process basis are important expressions of community desires for guiding future land use in Derry. As conditions change, it is important to reassess and revise the goals and policies. Legally, there are important reasons for maintaining a current master plan, since it serves as the basis for land use regulations and capital improvement programs for the town.

Watershed communities should review and update their master plans on a periodic basis. Every five years is recommended by RSA 674:2 VIII for local water resources management and protection plans.

b. Local Water Resources Management and Protection Plans

In 1986, the legislature established the Water Protection Assistance Program within the Office of State Planning (RSA 4-C:19). The purpose of the program is to encourage municipalities to evaluate their water resources and to develop measures for the protection of both groundwater and surface water. The statute directed OSP to develop administrative rules to provide guidance for municipalities in the development of local water resources management and protection plans, to be adopted as part of the conservation and preservation section of their master plans. The original rules took effect on January 20, 1988. Subsequent revisions to the rules were made on August 20, 1990, to simplify and add flexibility to the planning process. According to the rules, a local water plan should provide a descriptive evaluation of a municipality's watersheds to include wetlands, floodplains, lakes, ponds, rivers and perennial streams. Groundwater resources within the town should also be evaluated, to include bedrock as well as stratified drift aquifers. The water

Figure XI-3 Proposed B.M.P. Model For Stormwater Treatment



plan should identify potential threats to water resources and project the municipality's future need for these resources. After providing an analysis of the town's existing regulatory framework, the plan should present a strategy of both regulatory and non-regulatory mechanisms for the long term management and protection of the town's water resources. A local waterplan must be submitted to OSP for review and written comment relative to its consistency with the State rules, prior to local adoption.

The Town of Derry prepared a regional water resource management and protection plan in 1988. The plan was submitted to OSP for review, and was adopted as part of Derry's zoning ordinance. The intentions behind establishment of this zone are as follows:

NATURAL RESOURCES ZONING *Effective 2-4-88*
ARTICLE XI - WATER RESOURCES CONSERVATION ZONE - General Provisions
Section 1 - AUTHORITY AND PURPOSE

By the authority granted in N.H. RSA 674:16-17 and 674:20-21, and in the interest of public health, safety and general welfare, the Derry Water Resources Conservation Zone is hereby established to regulate the uses of lands subject to standing water, flooding, or extended periods of high water table.

a. *In order to control the development of structures and land uses within the zone which would contribute to the pollution of surface and groundwater.*

b. *In order to prevent the destruction of wetlands which provide flood protection, groundwater recharge, pollution abatement, and the augmentation of stream flow during dry periods, and which are important for such other reasons as those cited in RSA 483-A:1-b.*

c. *In order to prevent unnecessary or excessive expenses to the Town to provide and maintain essential services and utilities which arise because of unwise use of water resources.*

d. *In order to encourage those uses that can be appropriately and safely located in the water resources zone.*

e. *In order to preserve and enhance those aesthetic values associated with the water resources zone of this Town.*

f. *In order to protect wildlife habitats and maintain ecological balances.*

g. *In order to preserve and enhance that wildlife associated with the water resources zone.*

C. Local Regulatory Measures

1. Zoning

The purpose of a zoning ordinance is to regulate the use of land in a manner that promotes the health and welfare of a municipality. It should include requirements to lessen congestion in the streets, secure safety from fires, panic and other dangers, to provide adequate light and air, to prevent the overcrowding of land and to avoid undue concentrations of populations. The ordinance should be designed to facilitate adequate provision of an infrastructure to meet municipal needs for such services as transportation, solid waste facilities, water, sewerage, schools and parks.

RSA 674:16 authorizes the local legislative body of a city or town to adopt and amend a zoning ordinance for the purpose of promoting the health, safety or general welfare of the community. Such ordinances are designed to regulate and restrict the use of land within the municipality. They often include maximum limitations for the density, height, number of stories and sizes of buildings and other structures. They specify areas, or zones, within the municipality where land and structures can be used for business, industrial, residential and other purposes. A listing of land uses that are permitted and prohibited, or permitted by special exception, is usually included for each zone within the community. A variety of zoning techniques are available for lake management and protection; some are listed in Table XI-2. Portions of the Town of Derry Zoning Ordinance appear in Appendix XI-1.

2. Environmental Characteristics Zoning

It is common for municipalities to recognize the importance of critical resource areas by adding protective overlay districts to their townwide zoning ordinances. An overlay zone is so called because it adds special protective

Table XI-2

A variety of zoning techniques

TOPIC	DEFINITION
Facility Allocation System	The periodic allocation of existing capacity in public facilities, especially in sewer and water lines and arterial roads, to areas where development is desired while avoiding areas where development is not desired.
Development Moratorium/ Interim Development Controls	A temporary restriction of development through the denial of building permits, rezonings, water and sewer connections, or other development permits and incentives are adopted, or until the capacity of critically overburdened public facilities is expanded.
Special Protection Districts/ Critical Areas/ Environmentally Sensitive Areas	Areas of local, regional, or State-wide importance-critical environmental areas (for example, wetlands and shorelands with steep slopes); areas with high potential for natural disaster (for example, flood-plains and earthquake zones); and areas of social importance (for example, historical, archaeological, and institutional districts) - protected by a special development review and approval process, sometimes involving State-approved regulations.

From the Lake and Reservoir Guidance Manual, Second Edition, EPA, 1990.

requirements or higher standards within an area that is delineated as a special resource. The boundaries of that resource usually do not coincide with those of the regular zoning districts. Where the requirements of the districts differ, the more stringent of the two apply. This type of zoning has traditionally been used to protect wetlands, floodplains, watersheds, aquifers, steep slopes and shorelines. Table XI-3 presents a summary of the types of requirements that are likely to be found in overlay zoning ordinances to address these resources.

Delineation of the environmental overlay zoning districts usually depends on existing maps and data prepared by federal agencies such as the Soil Conservation Service, United States Geological Survey, Federal Emergency Management Agency and others. Although such maps provide the planning board with a general idea of the extent of the resource in question, they are generally not sufficient in detail to identify a precise location of the district boundary. Where this is the case, it is important for the overlay zoning ordinance to allow applicants to provide the planning board with more technical, site specific information to delineate the boundary. It is helpful to both the planning board and applicants if that section of the ordinance clearly defines the methodology or options for methodologies to be used to delineate the district in the field. The ordinance may provide for an independent review of the data which has been provided by the applicant, or by a qualified consultant hired by the planning board at the applicant's expense. This type of review and professional consultation assists the planning board in making an informed decision based on technical information about the sensitive resource that the ordinance aims to protect. The ordinance may also spell out conditions under which the planning board may require site specific investigations.

3. Wetlands Zoning

Many municipalities adopt wetlands overlay zoning regulations to protect the natural functions or values which make wetlands critical resources within a watershed. These important functions include flood protection and flow stabilization, wildlife habitat, filtration of nutrients, trapping of sediments, and ecological productivity. Such ordinances need to define or

Table XI-3

Overlay Zoning Techniques: Key Characteristics

Wetlands	Floodplains	Watershed
-Permitted and prohibited Uses*	-Permitted and prohibited uses*	-Permitted and prohibited uses*
-Setbacks for septic tanks leachfields*	-Setbacks for septic tanks /leachfields*	-Performance standards more stringent than generally required by zoning*
-Setbacks for roads and structures* -Buffers*	-Setbacks for wells, structures, roads* -Zero increase in peak flood elevation	-Site specific data requirement option
-Definition of wetlands and methodology for delineation*	-Site specific data option	
-Site specific data requirement option		

Aquifer	Steep Slopes	Shoreline
-Permitted and prohibited uses*	-Requirements for location or prohibition of septic systems vs. roads and structures*	-Buffers, setbacks and rationale*
-Definition and methodology for delineation of district* -More stringent performance standards than required by site review* -More stringent performance standards than watershed*	-Site specific data requirement option	-BMP's for lawn management natural vegetative buffers, etc.* -Requirements for shoreline structures* -Site specific data requirement option

delineate the extent of the overlay district boundary. There are a number of different ways of establishing the extent of wetland boundaries, the most commonly used criteria being soils, vegetation, and hydrology. Wetland overlay ordinances typically have requirements for setbacks from wetlands for the location of septic system tanks and leachfields, roads and structures. Some ordinances establish buffers around wetlands within which land uses are either restricted or required to adhere to performance standards. It is common for wetland ordinances to allow the planning board to require that site specific information relative to the location of the wetland boundary be supplied by the applicant. This is usually reserved for sites where considerable acreage of wetlands is proposed for alteration, or the wetlands exhibit particular resource values that are of significance to the municipality.

As part of its water resource protection plan, the Town of Derry has adopted a wetlands conservation district. Its purpose, and regulations taken from the Town of Derry Zoning Ordinance follow. Definitions of terms, special exceptions and exemptions can be found in Appendix XI-2.

Section 2 - WETLAND CONSERVATION DISTRICT

PURPOSE

In the interest of public health, convenience, safety and welfare, the regulations of this district are intended to guide the use of areas of land with periods of high water tables and/or permanent standing water. The specific intent of this district is:

a. *To prevent the development of structures or other land uses on naturally occurring wetlands which would contribute to pollution of surface and ground water.*
b. *To prevent the alteration of natural wetlands which provide flood protection, recharge of groundwater supply or augmentation of stream flow during dry periods.*
c. *To prevent unnecessary or excessive expenses to the Town to provide and maintain essential services and utilities which could arise because of inharmonious use of wetlands.*
d. *To encourage those uses that can be appropriately and safely located in wetland areas.*

e. *To create an undisturbed and natural buffer to the Prime Wetlands.*

f. *To protect unique and unusual natural areas.*

g. *To protect wildlife habitats and maintain ecological balances.*

Section 7 - REGULATIONS

Section 7.1 - PRIME WETLANDS AND PRIME WETLANDS BUFFER ZONES

A. Permitted Uses: Permitted uses in areas designated as prime wetlands and/or prime wetlands buffer zones are as follows:

1. *Wildlife habitat development and management.*
2. *Conservation areas and nature trails.*
3. *Cultivation and harvesting of crops according to recognized soil conservation practices including the protection of the prime wetlands from pollution caused by fertilizers, pesticides, and herbicides used in such cultivation.*

B. Conditional Uses: A conditional Use Permit may be granted by the Planning Board (RSA 674:21 II) for the following purposes:

1. *Forestry and tree farming within the buffer zone using best management practices in order to protect prime wetlands from damage, to prevent sedimentation, and to prevent destruction of wildlife habitats, provided that any forestry and/or tree farming activities shall first be reviewed and approved by the Conservation Commission. Final approval shall be given by the Planning Board.*

2. *The construction of fences, footbridges, catwalks, and wharves only, provided:*

   1. *said structures are constructed on posts or pilings so as to permit the unobstructed flow of water;*
   2. *the natural contour of the prime wetland is preserved;*
   3. *the Conservation Commission has first reviewed and approved the proposed construction; and*

4. the Planning Board has received Conservation Commission approval in writing and has reviewed the proposed construction.

Prior to the granting of a Conditional Use Permit under this section, the applicant shall agree to submit a performance security to the Planning Board. The Security shall be submitted and approved prior to issuance of any permit authorizing construction. The security shall be submitted in a form and amount, with surety and conditions satisfactory to the Conservation Commission and approved by the Planning Board, to ensure the construction has been carried out in accordance with the approved design.

The Planning Board, with the concurrence of the Conservation Commission, may require the applicant to submit an environmental impact assessment when necessary to evaluate an application made under this section. The cost of this assessment shall be borne by the applicant. The Planning Board may also assess the applicant reasonable fees to cover the costs of other special investigative studies and for the review of documents required by particular applications.

4. Floodplain Zoning

Floodplains are sensitive resources that are often protected by local zoning. Their values include their ability to protect adjacent properties from damage by assimilating flood waters during storm events. Many also serve as critical wildlife areas, and either are wetlands or are associated with wetland habitats. Communities are required by the Federal Emergency Management Agency (FEMA) to pass certain minimal zoning restrictions for floodplain development, in order to be eligible for the federal flood insurance program. Many communities choose to adopt floodplain requirements in their zoning ordinances which are more stringent than the minimum required by the FEMA program. The FEMA program allows construction within sensitive floodplain areas if the structures are "floodproofed." Filling in or paving over floodplains decrease the peak flow capacity of the riverine system. The cumulative impacts of filling or paving, over time, can have a significant impact on downstream properties. Municipalities can adopt more stringent overlay zoning requirements than FEMA's, to provide protection measures for floodplain areas. Floodplain ordinances can include setbacks and site specific data requirements that are similar to those found in wetlands ordinances. Requirements for maximum or no increases in peak flood levels are often considered in floodplain zoning ordinances.

The Town of Derry has developed an overlay floodplain development ordinance which is in accordance with the requirements of the National Flood Insurance Program. This ordinance requires that new and replacement water supply and wastewater disposal systems are located, constructed and designed to minimize and/or avoid destruction caused by flood events. The item, taken from the Town of Derry Zoning Ordinance apppears here. Definition of terms in the agreement (Item 1) appears in Appendix XI-3.

Derry Floodplain Development Ordinance

The following regulations shall apply to all lands designated as special flood hazard areas by the Federal Emergency Management Agency in its "Flood Insurance Study for the Town of Derry, N.H." together with the associated Flood Insurance Rate Maps (FIRM) and Flood Boundary and Floodway maps of the Town of Derry, N.H. dated April 15, 1981, which are declared a part of this ordinance.

ITEM II

All proposed development in any special flood hazard areas shall require a permit.

ITEM III

The Building Inspector shall review all building permit applications for new construction or substantial improvements to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a flood-prone area, all new construction and substantial improvements shall:

1. *be designed (or modified) and adequately anchored to prevent flotation, collapse or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy.*
2. *be constructed with materials resistant to flood damage.*

3. *be constructed by methods and practices that minimize flood damage.*
4. *be constructed with electrical, heating, ventilation, plumbing and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding.*

ITEM IV

Where new and replacement water and sewer systems (including on-site systems) are proposed in flood prone areas the applicant shall provide the Building Inspector with assurance that new and replacement sanitary sewage systems will be designed to minimize or eliminate infiltration of flood waters into the systems and discharges from the systems into flood waters, and on-site waste disposal systems will be located to avoid impairment to them or contamination from them during periods of flooding.

ITEM V

The Building Inspector shall maintain for public inspection, and furnish upon request, any certification of flood-proofing and the as built elevation (in relation to mean sea level) of the lowest floor (including basement) of all new or substantially improved structures, and include whether or not such structures contain a basement. If the structure has been flood-proofed, the as built elevation (in relation to mean sea level) to which the structure was flood-proofed. This information must be furnished by the applicant.

ITEM VI

The Building Inspector shall review proposed developments to assure that all necessary permits have been received from those governmental agencies from which approval is required by Federal or State law, including Section 404 of the Federal Water Pollution Control Act Amendments of 1972, 33 U.S.C. 1334. It shall be the responsibility of the applicant to certify these assurances to the Building Inspector.

ITEM VII

In riverine situations, prior to the alteration or relocation of a watercourse, the applicant for such authorization shall notify the Wetlands Board of the New Hampshire Environmental Services Department and submit copies *of such notification to the Building Inspector. Further, the applicant shall be required to submit copies of said notification to those adjacent communities as determined by the Building Inspector.*

Within the altered or relocated portion of any watercourse, the applicant shall submit to the Building Inspector, certification provided by a registered professional engineer assuring that the flood carrying capacity of the watercourse has been maintained.

Along watercourses that have a designated Regulatory Floodway no encroachments, including fill, new construction, substantial improvements, and other development are allowed within the designated Regulatory Floodway that would result in any increase in the flood levels within the community during the base flood discharge. In Zone A the Building Inspector shall obtain, review and reasonably utilize any floodway data available from a Federal, State or other source as criteria for requiring that development meet the floodway requirements of this section.

Along watercourses that have not had a regulatory floodway designated, no new construction, substantial improvements or other development (including fill) shall be permitted within Zones A1-30 and AE on the FIRM, unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one foot at any point within the Community.

ITEM VIII

1. In special flood hazard areas the Building Inspector shall determine the 100 year flood elevation in the following order or precedence according to the data available.

- *a. In Zones A1-30, AH, AE, V1-30 and VE refer to the elevation provided in the communities Flood Insurance Study and accompanying FIRM or FHBM.*
- *b. In unnumbered A zones the Building Inspector shall obtain, review, and reasonably utilize any 100 year flood elevation data available from the Federal, State development proposals submitted to the community (example subdivisions, site approvals, etc.) or other source.*

c. *In Zone AO the 100 year flood elevation is determined by adding the elevation of the highest adjacent grade to the depth number specified on the FIRM or if no depth number is specified on the FIRM at least two feet.*

2. The Building Inspector's 100 year flood elevation determination will be used as criteria for requiring in Zones A1-30, AE, AH, AO and A that:

a. *all new construction and substantial improvements of residential structures have the lowest floor (including basement) elevated to or above the 100 year flood level;*

b. *that all new construction and substantial improvements of non-residential structures have the lowest floor (including basement) elevated to or above the 100 year flood level; or together with attendant utility and sanitary facilities, shall:*

(i) *be flood-proofed so that below the 100 year flood elevation the structure is watertight with walls substantially impermeable to the passage of water;*

(ii) *have structural components capable of resisting hydrostatic and hydrodynamic loads and the effects of buoyancy; and*

(iii) *be certified by a registered professional engineer or architect that the design and methods of construction are in accordance with accepted standards of practice for meeting the provisions of this section.*

c. *all manufactured homes to be placed or substantially improved within special flood hazard areas shall be elevated on a permanent foundation such that the lowest floor of the manufactured home is at or above the base flood level; and be securely anchored to resist flotation, collapse or lateral movement. Methods of anchoring may include, but are not limited to, use of over-the-top or frame ties to ground anchors. This requirement is in addition to applicable State and Local anchoring requirements for resisting wind forces;*

d. *for all new construction and substantial improvements, fully enclosed areas below the lowest floor that are subject to flooding are permitted providing the enclosed areas meet the following requirments:*

1. *the enclosed area is unfinished or flood resistant usable solely for parking of vehicles, building access or storage.*

2. *the area is not a basement.*

3. *shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters.*

Designs for meeting these requirements must either be certified by a registered professional engineer or architect or must meet or exceed the following minimum criteria: A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be no higher than one foot above grade. Openings may be equipped with screens, louvers or other coverings or devices provided that they permit the automatic entry and exit of floodwaters;

e. *proposed structures to be located on slopes in Special Flood Hazard Areas, Zones AH and AD, shall include adequate drainage paths to guide flood waters around and away from the proposed structures.*

NOTE: *The above Section 2.0 to this point/Effective 8-21-87*

5. Watershed Zoning

Some communities have recognized the importance of particular watersheds by adopting watershed protection overlay districts. This is common where there is either a public surface water supply or a particular watershed contributing recharge to a groundwater supply. It is also common for watershed zoning to be used to protect a surface waterbody that is considered a critical resource for reasons other than drinking water supply. Such ordinances usually specify land-uses which are permitted or prohibited within the watershed. With outright prohibition of land uses within an entire watershed, the potential for a "taking" issue may come into play. The emphasis, therefore, is usually on performance standards that are somewhat more specific or stringent than those required for the rest of the community. Such standards should be designed to address protection of the specific resource values for which the watershed is considered locally important. In many instances the land of a significant watershed may lie within a number of municipalities. In these cases it may be appropriate for each community to adopt the same performance standards for the portion of the watershed that is within their town. This is one way to assure consistent protection throughout the entire hydrologic system.

The watershed zoning approach should be considered by the Town of Derry.

6. Aquifer Zoning

There has been an increased interest in local groundwater protection, stemming from a growing public awareness about groundwater contamination occurrences. The State-USGS cooperative aquifer mapping program is making available improved information about stratified sand and gravel aquifers on a statewide basis. In order to protect these areas for future use as potential water supplies, many municipalities have adopted aquifer zoning districts. These ordinances generally list permitted and prohibited uses. To a large extent, they also rely on performance standards for future land uses to minimize the chances of aquifer contamination resulting from new development. Such standards often include provisions that require containment structures for uses involving the presence of dangerous materials. Treatment swales to control stormwater flows and ensure infiltration for groundwater recharge are also common. Due to their high rates of transmissivity and permeability, aquifer areas that may serve as existing or future water supplies are sensitive to potential pollutants. This is generally considered to be justification for more stringent performance standards than are imposed throughout the municipality.

At the present time there are no surface waters within Derry which are considered to be potential water supplies. The town currently purchases water from the Manchester Water Works Department which is obtained from Lake Massabesic. An aquifer map of the area has been assembled, and several low, medium and high yield aquifers have been delineated within the towns' boundaries. Although there is not a great demand for them at the present time, future development in the area may place strains on the current water supply and cause their value as a natural resource to increase.

The Southern New Hampshire Planning Commission put together a Water Resource Mangement and Protection Plan for the Town of Derry. Here, in its section on aquifers, it lists potential threats and makes suggestions for protection for this resource.

Management of Potential Threats

All existing and future land use activities, particularly those which do or will use or discharge water, must be considered to be potential threats to the community's surface and groundwater resources.

It has been estimated that approximately 5,100 dwelling units are currently served by subsurface wastewater disposal systems. Little is known about the condition of these facilities; however, research material reviewed by the Southern New Hampshire Planning Commission in the course of preparing the "Septage Management Study for the Southern New Hampshire Planning Sub-region" (June 1987) revealed that there is an apparent general lack of knowledge by the public concerning septic tank and leach field operation and maintenance, a situation which could indicate that some of these systems may now, or could in the future, be subject to failure.

Other potential problem areas in the community, as evidenced by the relationship between existing land use and water quality concerns include the following:

1. *One hundred and twenty-six (126) active and abandoned underground petroleum storage tanks have been identified in Derry. Many of these should be of particular concern because they are either over an identified aquifer, or are in proximity to streams which appear to drain to or in the direction of aquifers.*

2. *The New Hampshire Department of Transportation and the Town of Derry salt storage facilities are located over potential medium-yield aquifers.*

3. *The municipal sanitary landfill site and the solid waste transfer station are located over a potential medium-yield aquifer.*

5. *Portions of N.H. Route 102, Birch Street, Rockingham Road, Island Pond Road, Gulf Road, and the Londonderry Turnpike are located over potential medium-yield aquifers and are salted during the winter.*

6. *The Hoodkroft Country Club has been identified as a pesticide application site adjacent to Beaver Brook less than a mile upstream from a potential medium-yield aquifer.*

7. *Concentrations of high density residential development utilizing subsurface wastewater disposal systems are located along the westerly and southerly shores of Beaver Lake.*

Several means are available to the town to help address these concerns and thereby improve upon current methods of protecting and managing the community's water resources. These include the following:

1. *Consideration should be given to the enactment of regulatory controls which would prohibit the subsurface storage of petroleum, petroleum products and materials over known aquifers.*

2. *The New Hampshire Department of Transportation should be encouraged to move its uncovered outside salt pile indoors, and to closely monitor, by the use of wells or other reliable method, possible leaching effects on the aquifer. The Town of Derry should similarly monitor leaching effects in the vicinity of its salt storage sheds. The ideal protective mechanism in each case is to relocate all salt storage facilities away from the aquifers.*

3. *Salt spreaders used by state and local highway crews should be calibrated frequently to minimize the potential for surface and groundwater contamination, not only in the vicinity of the aquifers, but throughout the town. State and local highway officials should consider whether or not it would be practical to discontinue the salting of road segments which lie over aquifers and use sand instead.*

4. *Pesticides, herbicides and fertilizers should be used sparingly to minimize runoff which could be potentially damaging to surface and groundwater resources.*

5. *Another site, away from the aquifers, should be established for snow dumping.*

6. *Public sewer collection system extensions should be given a high priority in order to help eliminate the potential risk of surface and/or groundwater contamination in existing developments having histories of septic system failures.*

The Water Supply and Pollution Control Division of the New Hampshire Department of Environmental Services has declared, as part of its permit process, that all groundwater of the State is a potential water supply. Potential groundwater sources are of two types: surficial deposits (sand and gravel aquifers) or bedrock aquifers. Unfortunately, more information is available regarding the water-bearing potential of the sand and gravel aquifers than about the bedrock aquifers. Until expensive and time-consuming hydrogeological investigations are undertaken, and their results made available, groundwater portection efforts should concentate on the sand and gravel aquifers. We recommend that the salt storage facilities and snow dumping areas are restricted not only in aquifer zones but also in the environmentally sensitive zones around surface water.

7. Steep Slopes Zoning

Steep slopes are quite vulnerable to erosion and subsequent sedimentation of water courses when exposed by disturbance of land and vegetation. For this reason, many communities prohibit the location of roads, structures and septic systems in areas with excessive slopes. Some communities have mapped areas with a slope greater than a certain percentage, and consider these areas as an overlay district. Some simply specify, in the text of the ordinance, that land with greater than a certain percent slope cannot be built upon or used in calculations to fulfill minimum lot size requirements.

Presently, erosion and sedimentation concerns are protected in Derry by the Earth Removal Ordinance. This ordinance regulates excavation, grading, filling, or removal of earth, loam, topsoil, sand, gravel, clay or stone. The purpose of this ordinance is to protect the ecological processes which are dependent upon physiography. These include protection of well water supplies, minimization of rapid surface runoff and preservation of cover crops to prevent erosion and control excavation.

Permits for removal are issued by the planning board upon receipt of an application and maps and plans which show valuable resources in the area and protection plans for them during and after excavation. The regulations of the ordinance give final slope requirements. Regulations from the Town of Derry Earth Removal Ordinance can be found in Appendix XI-4.

8. Shoreland Zoning

A concern about disturbance of natural shorelands arose from the increase in demand for and the value of waterfront property. Devegetated, exposed shorelands are subject to erosion from increased wave action due to storm and boating pressures. Further removal of natural shore vegetation leaves the land vulnerable to storm event related erosion. The installation of lawns along the shore often leads to the introduction of fertilizers and pesticides. Many municipalities with lake and river shorelands are responding to this concern by developing overlay zoning ordinances that address specific lacustrine (lake) and riverine habitat problems. Consideration is being given to minimum frontage requirements and setbacks from surface water for septic systems, structures and other alterations of terrain.

The waterbodies of Derry are protected at the present time by the Water Resources Conservation Zone (Article XI of the Derry Town Ordinances). The purpose of the article is to regulate the uses of lands subject to standing water, flooding, or extended periods of high water table. It is, therefore the same article by which the town wetlands are protected. Section 7.2 regulating poorly drained and very poorly drained soils follows.

Section 7.2 - POORLY DRAINED AND VERY POORLY DRAINED SOILS
(other than Prime Wetlands)

A. *Permitted Uses: Any of the following uses that do not result in the erection of any buildings and that are otherwise permitted by the Zoning Ordinance:*

1. *Poorly Drained Soils: Permitted uses in areas of poorly drained soil are as follows:*

a. *Any use otherwise permitted by the Zoning Ordinance and State and Federal laws that does not involve the erection of a structure and that does not alter the surface configuration of the land by the addition of fill or by dredging except as a common treatment associated with a permitted use.*

b. *Cultivation and harvesting of crops and according to recognized soil conservation practices including the protection of the wetlands from pollution caused by fertilizers, pesticides and herbicides used in such cultivation.*

c. *Forestry and tree farming using best management practices in order to protect poorly drained soils and streams from damage and to prevent sedimentation.*

d. *Wildlife habitat development and management.*

e. *Recreational uses consistent with the purpose and intent of this article as defined in the General Provisions and the Purpose stated in this section.*

2. <u>Very Poorly Drained Soils</u>: Permitted uses in areas containing very poorly drained soils, marshes, open water and perennial streams are as follows:

a. *Uses specified under Section A.1 (a through f) shall be permitted; except that no alteration of the surface configuration of the land by filling or dredging and no use which results in the erection of a structure, except as provided for in Section A.2 (b) below, shall be permitted.*

b. *The construction of fences, footbridges, catwalks and wharves only, <u>provided</u>:*

1. *said structures are constructed on posts or pilings so as to permit the unobstructed flow of water;*
2. *the natural contour of the wetland is preserved;*
3. *the Conservation Commission has first reviewed and approved the proposed construction; and*
4. *the Planning Board has received Conservation Commission approval in writing and has reviewed and approved the proposed construction.*

3. <u>Bogs</u>: Permitted uses in bogs only.

a. *The construction of fences, footbridges, catwalks and wharves only, provided:*

1. *said structures are constructed on posts or pilings so as to permit the unobstructed flow of water;*
2. *the natural contour of the wetland is preserved;*
3. *the Conservation Commission has first reviewed and approved the proposed construction; and*

4. *the Planning Board has received Conservation Commission approval in writing and has reviewed and approved the proposed construction.*

B. Conditional Uses: A Conditional Use Permit may be granted by the Planning Board (RSA 674:21 II) for the construction of roads and other access ways; and for pipelines, powerlines and other transmission lines; water impoundment and the construction of well water supplies; and drainage ways to include streams, creeks or other paths of normal runoff water and common agricultural land drainage; provided that all of the following conditions are found to exist:

1. *The proposed construction is essential to the productive use of land not within the Wetlands Conservation District.*
2. *Design and construction methods will be such as to minimize detrimental impact upon the wetland, and the site will be restored as nearly as possible to its original condition.*
3. *No alternative which does not cross a wetland or has less detrimental impact on the wetland is feasible.*
4. *Economic advantage alone is not reason for the proposed construction.*

The Planning Board, with the concurrence of the Conservation Commission, may require the applicant to submit an environmental impact assessment when necessary to evaluate an application made under this section. The cost of this assessment shall be borne by the applicant. The Planning Board may also assess the applicant reasonable fees to cover the costs of other special investigative studies and for the review of documents required by particular applications.

Prior to the granting of a Conditional Use Permit under this section, the applicant shall agree to submit a performance security to the Planning Board/Public Works Department. The security shall be submitted in a form and
amount, with surety and conditions satisfactory to the Public Works Director and approved prior to issuance of any permit authorizing construction.

C. Special Provisions:

1. *No waste disposal systems shall be located closer than seventy-five (75') feet to any wetland.*

2. *All construction, forestry and agricultural activities within one hundred (100') feet of any wetland shall be undertaken with special care to avoid erosion and siltation into the wetlands.*

3. *Where an existing use within the setback is destroyed or in need of extensive repair it may be rebuilt provided that such rebuilding is completed within one year of the event causing destruction, the new or rebuilt use shall not extend further into the wetland or setback area than the original use.*
4. *No buildings shall be located closer than Seventy-Five (75') feet to any wetland one acre or larger in size and no building shall be located closer than thirty (30') feet to any wetland less than one acre in size.*

D. Special Exceptions:

Upon application to the Board of Adjustment, a special exception shall be granted to permit the erection of a structure within the Wetland Conservation District on vacant lots provided that all of the following conditions are found to exist:

1. *The lot upon which an exception is sought was an official lot of record, as recorded in the Rockingham County Registry of Deeds prior to the date of the first legal notice pertaining to this ordinance, posted and published in the Town of Derry, NH.*
2. *The use for which the exception is sought cannot feasibly be carried out on a portion or portions of the lot which are outside the Wetland Conservation District.*
3. *Due to the provisions of this ordinance, no reasonable and economically viable use of the lot can be made without the exception.*
4. *The design and construction of the proposed use will, to the extent practical, be consistent with the purpose and intent of this Article.*
5. *The proposed use will not create a hazard to individual or public health, safety and welfare due to the loss of wetland, the contamination of ground water, or other reason.*

E. Filled Lands and Pre-existing Uses

1. *Lands, which may have been wetlands but were filled under properly issued state and town permits granted prior to the adoption of this ordinance shall be judged according to the soils and flora existing at the site at the time application for building permit or subdivision is made.*

2. *Structures and uses existing at the time of the adoption of this ordinance may be continued provided that such use shall not be expanded to encroach further upon the wetlands or designated setback areas.*

F. Exemption for Residential Structures

Notwithstanding other provisions of this Article, the construction of additions and extensions to one and two family dwellings shall be permitted within the wetland Conservation District provided that:

1. *The dwelling lawfully existed prior to the effective date of this Article. (2-4-88).*
2. *That the proposed construction conforms with all other applicable ordinances and regulations of the Town of Derry.*

Further protection of shorelands is provided by the Earth Removal Ordinance, Subdivision Regulations and Site Plan Review Regulations.

The Town of Derry has done much to ensure safekeeping of their water resources. The Natural Resources Zoning, and specifically the Water Resources Conservation Zone ensure that these valuable assets will have protection in the future. However, more can still be done.

We recommend that a Lake Protection District be set up by the Town of Derry. This District is defined as an environmentally sensitive area surrounding the lakes and ponds of Derry in which development activities must be closely regulated to preserve the lake quality. This protection district should also include each sub-drainage basin to the lake. Since land use in the lake's watershed is the key to nutrient and sedimentation rates to the lake, more effort must be devoted to this important element. The adoption of the State's Shoreland Protection Act would be a great benefit to protecting the town's waterbodies.

A Shoreland Protection Act was passed by both the Senate and House of Representatives during the 1991 legislative session, although most of the requirements of the Act are not effective at the time of this report. With the concern that the protection of this states waterbodies is a primary goal, the general court found:

- The shorelands of the state are among its most valuable and fragile natural resources and that their protection is essential to maintain the integrity of public waters.

- The public waters of New Hampshire are valuable resources held in trust by the state and the state has an interest in preserving those waters and has the jurisdiction to control the use of the public waters and the adjacent shoreland for the greatest public benefit.

- There is great concern throughout the state relating to the utilization, protection, restoration and preservation of shorelands because of their effect on state waters.

- Under current law the potential exists for uncoordinated, unplanned and piecemeal development along the state's shorelines, which could result in significant negative impacts on the public waters of New Hampshire.

To fulfill the state's role as trustee of its waters and to promote public health, safety, and the general welfare, the General Court declared that the public interest requires the establishment of standards for the subdivision, use and development of the shorelands of the state's public waters. The development standards provided in this Chapter shall be the minimum standards necessary to protect the public waters of the State of New Hampshire. These standards shall serve to:

- Further the maintenance of safe and healthful conditions.
- Provide for the wise utilization of water and related land resources.
- Prevent and control water pollution.
- Protect fish spawning grounds, aquatic life, bird and other wildlife habitats.
- Protect buildings and lands from flooding and accelerated erosion.
- Protect archeological and historic resources.
- Protect commercial fishing and maritime industries.
- Protect freshwater and coastal wetlands.
- Control building sites, placement of structures and land uses.

- Conserve shore cover, and visual as well as actual points of access to inland and coastal waters.
- Preserve the state's rivers, lakes, estuaries and coastal waters in their natural state.
- Promote wildlife habitat, scenic beauty, and scientific study.
- Protect public use of waters, including recreation.
- Conserve natural beauty and open spaces.
- Anticipate and respond to the impacts of development in shoreland areas.

The shoreland protection standards were designed to minimize shoreland disturbance so as to protect public waters, while still accommodating reasonable development in the protected shoreland. More stringent standards for the shoreland protection area may be adopted by the local government.

The minimum shoreland protection standards are listed below and summarized on Table XI-4.

Protected Shoreland Restrictions (within 250 feet of a lake)

- Salt storage yards, auto junk yards, and solid or hazardous waste facilities shall be prohibited.
- Primary structures shall be set back behind the primary building line. This line shall require a minimum setback of 50 feet from the public boundary line (lake shore).
- Water dependent structures, such as docks, piers, breakwater or other structures, built over, on, or in the state waters shall be constructed only as approved by the wetlands board pursuant to RSA 482A.
- The application of any fertilizer, pesticide or herbicide within 125 feet of the public boundary line for noncommercial private purposes shall be prohibited.
- A natural woodland buffer shall be maintained within 150 feet of the public boundary line to protect the quality of public waters by minimizing erosion, preventing siltation and turbidity, stabilizing soils, and reducing phosphorus loading.

Table XI-4

PROTECTED SHORELAND STANDARDS

LIMITS OF PROTECTED SHORELAND

- Lot size by soil type
- Lot width at 150'
- Alteration of Terrain Permit standards reduced from 100,000 SF to 50,000 SF
- Salt storage yards, auto junk yards, solid waste and hazardous waste facilities prohibited
- Erosion and Siltation Controls

250'

LIMITS OF CUTTING RESTRICTIONS

- 1/2 basal area every 20 years (Duplicates existing Timber Laws)

150'

SEPTIC SYSTEM SETBACKS

- Start at 125'
- Reduce to 75' as conditions permit
- Prohibit fertilizers, pesticides and herbicides

125'

75'

PERMANENT BUILDING LINE

Primary buildings behind line

In front, may have:

- Accessory buildings
- Water dependent structures approved by wetlands board

50'

PUBLIC BOUNDARY LINE

- Septic systems within the protected shoreland are subject to the department's subdivision approval requirements pursuant to RSA 485-A:29 regardless of size.

  The following conditions shall dictate the setback requirements for septic systems:
- If the downgradient soil is a porous sand and gravel material with a percolation rate of more than two minutes per inch, the setback shall be at least 125 feet from the public boundary line;
- For soils with restrictive layers within 18 inches of the natural soil surface, the setback shall be at least 100 feet from the public boundary line; and
- For all other soil conditions, the setback shall be at least 75 feet from the public boundary line.
- All new structures within the protected shoreline shall be designed and constructed in accordance with the current rules of the department promulgated pursuant to RSA 485-A:17 for controlling erosion, siltation and phosphorus loading to public waters during and after construction.
- The minimum size for new lots in areas dependent upon on-site septic systems shall be determined by soil type lot size determinations, as set forth in the department's current administrative rules promulgated pursuant to RSA A 485-A.

d. Land Management and State Government

As we have stressed throughout this Chapter, the manner in which man uses the land and/or its resources within the watershed will play a major role in the maintenance or degradation of water quality standards. Each of the major categories of management practices is reviewed in the following sections and recommendations made relative to the proper application of each, along with a notation of applicable state laws which regulate the manner in which these practices are carried out.

1. Agriculture

A variety of management practices, implemented at individual farm sites, can reduce or eliminate the potential for adverse water quality impacts.

These include:

- Manure Storage and Spreading - manure should be stored in a facility which reduces or eliminates the potential for runoff or leaching of nutrients into watercourses. Manure spreading should be conducted only when the ground is not frozen or wet. In those instances where plowing is anticipated, such action should commence as near to the date of spreading as possible.
- Land clearing - in all instances where land areas are cleared for the purpose of providing additional cropland or pastureland, the clearing operation should be conducted in a manner which reduces the potential for erosion and sedimentation. (See Silvicultural Activities.)
- Alteration of drainage courses, pond construction and filling of wetlands - management practices designed to increase the amount of land utilized for cultivation, unless conducted in a manner acceptable to the appropriate state agencies and their established guidelines, can significantly affect the level or water quality within the watershed. Existing and altered drainage courses must be managed so that the potential for streambank erosion is eliminated. Strict guidelines relative to pond construction, which reduce or eliminate sedimentation and erosion during construction and eliminate the potential for dam failure or improper overflow during peak flow periods, should be followed. Wetlands and marsh areas, especially near stream systems, should be protected as a means of reducing flow velocities, thereby reducing erosion potential and dispersing and reducing sediments and nutrient loading.
- Access to running water - in all cases, direct access to running water (streams, rivers, etc.) by farm animals should be eliminated. Water supply to farm animals should be provided from a tank or alternate system which is located at a reasonable distance from all sources of surface water.
- Chemical Fertilization-Pesticide, Herbicide and Fungicide - in those instances where chemical fertilizers or pesticides are used, the application of such should be conducted in manner which limits the potential for runoff and/or contamination of water systems. This can be achieved by tilling the soil immediately following the

application of fertilizer and reducing the use of fertilizers and pesticides within a 125 foot distance of standing or running water.

Each of these recommended management practices relies almost entirely upon the individual landowner for compliance. Some will require capital outlays to achieve these goals. Financial assistance from U.S.D.A. agencies and educational programs directed toward landowners should be made available whenever possible. Existing state laws that govern specific agricultural practices are included in Table XI-5.

2. Silvicultural Activities

Timber harvest and silviculture practices, if conducted in an improper manner, can contribute significantly to stream sediment and nutrient levels, thereby affecting the level of water quality within the watershed. The following management practices are recommended as a means of reducing adverse impacts from these activities.

- Road Construction - Properly designed skid roads, which do not exceed a gradient of 10% and incorporate the use of water bars for drainage purposes, substantially reduce the potential for erosion and sedimentation. In those instances where stream crossings are required, construction of a log bridge and proper attention to stream bank alteration should be implemented by the logger.
- Clear Cutting - In areas of thin soil cover or shallow to bedrock soil characteristics, clear cutting should be minimized to reduce the potential for erosion and nutrient release. In addition, in all areas in which clear cutting practices are conducted, a vegetation buffer area in excess of 100 feet should be maintained around all surface water areas.

State statutes which regulate silviculture practices and timber harvesting are included in Table XI-6.

3. Construction Practices

Construction operations, whether it be a single family home or a major industrial expansion, can place a severe burden on water quality within the

Table XI-5
State Laws Governing
Agricultural Practices

Revised Statute Annotate	Subject	Governing Agency
RSA 482-A	Dredge and Fill	DES, WRB
RSA 485-A:17	Significant alteration of the terrain	DES, WSPCD
RSA 224:44-a	Cutting near public water or highways	Forest and Lands
RSA 485-A:12-15	Limiting disposal of waste	DES, WMD
RSA 79:10	Notice of intent to cut	NH Dept. of Revenue
RSA 430:28-48	Pesticide control act	Pesticide Control Division
RSA 430:284B	Economic Poisons Act	Pesticide Control Division
RSA 431:33	Regulation of handling of Manure, Agricultural Compost and Chemical Fertilizers	Dept. of Agriculture

Table XI-6

State Laws Governing

Silviculture Practices

Revised Statute Annotated	Subject	Governing Agency
RSA 224:44-a	Cutting near public water or highway	Forest and Lands
RSA 224:44-6	Care of slash or mill wastes	Forest and Lands
RSA 79:10	Notice of intent to cut	NH Dept. of Revenue
RSA 485-A:17	Significant alteration of the terrain	DES, WSPCD
RSA 482-A	Dredge and fill	DES, WRD

watershed unless closely monitored. Standard practices which reduce the level of erosion and sedimentation should be incorporated at all times. These practices can be enforced by the building inspector of the local municipality as well as by state officials to ensure conformity. These practices include:

- Building Permits - Included within a standard building permit application should be a provision which requires the contractor to incorporate management practices which reduce the potential for soil erosion and sedimentation. Nonconformity to these practices should result in the revocation of such a permit and the issuance of a cease and desist order.
- Site Work - During actual construction, care should be taken to reduce erosion through such control measures as mulching of disturbed soils surfaces and excessive gradients, construction of sediment retention ponds in those instances where surface water is disrupted and phasing of construction when possible to reduce the gross land area which may be exposed or disturbed at any one point in time. Site preparation, such as clearing or grading, should be monitored and practices incorporated similar to those outlined under Timber Harvest and Silviculture Practices.
- Road Construction - Construction of new roadways and the alteration of existing roadways should be conducted so as to eliminate erosion problems. Roadway lane surfaces (dirt roads) and shoulders should be constructed so as to reduce erosion. Roadside gradients should be no more than 3:1 and mulched as soon after construction as possible. Proper drainage should be provided through use of appropriately designed culverts and ditching alongside roadways. Drainage should be designed such that stormwater runoff from roads and other impervious surfaces is minimal. Construct areas that allow for infiltration of the stormwater.

The incorporation of these broad construction practices can produce substantial results. However, it cannot be left solely to the contractor to ensure the implementation of such practices. While local municipalities can enforce proper practices through the building permit program, assistance and support from the state is available through the enforcement of the statutes listed in Table XI-7.

Table XI-7

State Laws Governing Construction Practices

Revised Statute Annotated	Subject	Governing Agency
RSA 79:10	Notice of intent to cut	NH Dept. of Revenue
RSA 36:19-29 & 34	Local subdivision regulation	Municipality
RSA 485-A:29-35	Subdivision Regulations	DES, WSPCD
RSA 482-A:21	Excavation & dredging	DES, WRD
RSA 485-A:17	Significant alteration of the terrain	DES, WSPCD
RSA 224:44-a	Cutting near public water or highways	forest and lands

4. Lawn Fertilizers

The practice of lawn fertilization in areas adjacent to surface waters has the potential of increasing nutrient loading to the water. Regulation of this practice can be handled at the local or state level. The adoption of a Shoreland Protection District should include restricting such practices within 125 feet of any water surface. This sort of ordinance requires close monitoring by the local municipality during the spring and summer months.

5. Gravel Pits

The location of gravel pits and the manner in which the material is removed from the site should be closely monitored by local officials. Gravel pits should not be permitted in any location where increased runoff will result in sedimentation of surface waters due to erosion. Where possible, inactive pits should be graded to reduce excessive slopes, thereby reducing the potential for runoff and sedimentation.

R.S.A. 155-E governs the excavation of earth. This law places the burden upon the landowner to obtain a permit from the municipality within which the proposed excavation is planned. In this manner control over excavation of material is retained by the municipality.

e. Watershed Management Summary

Development within the watershed of a lake which fails to take into account the carrying capacity of the land will serve to lessen the value of the lakes. Management of the watershed, which ensures the maintenance of adequate water quality standards and prevents future degradation of water quality, is of obvious importance to the local municipalities from both an economic and environmental standpoint.

Each of the recommended management practices outlined above will require incentives to ensure conformity to, and implementation of, these recommendations. Management practices are more difficult to monitor and enforce than regulatory controls and therefore require alternative means of implementation.

In order to provide for proper management, specific regulatory controls should be incorporated at the local level. Controls should include the determination of lot sizing according to the soil and slope characteristics, enforcement of shoreline setbacks and the control of seasonal cottage conversions to year round residences. Existing state laws lend support to the incorporation of these specific practices. Land management practices relative to agriculture, timber harvest, construction and gravel pit operation require more of a commitment by individual landowners and operators. Enforcement of specific regulations relative to management practices exists primarily at the state level. However, local municipal officials should play a major role in the identification and documentation of potential violations. Local ordinances can be adopted which conform closely to existing state regulations. In this manner, local ordinances supplement state regulations and provide support for existing state laws. Each recommendation will involve some degree of personal sacrifice. However, this price is small in comparison to the economic, environmental and aesthetic values to be realized by a watershed with a high level of water quality.

While financial incentives to logging operations and construction firms are limited, educational programs designed to inform these operators can be implemented, thereby reducing their potential for costly delays due to time limitations.

Most other management practices require monitoring by local officials who can then notify state authorities when violations of state regulations are documented. This review by the municipal officials is the most effective manner in which these laws can be monitored and enforced.

Programs currently exist at the federal level, through the United States Department of Agriculture (U.S.D.A.) which provide for cost sharing of certain conservation projects. Educational methods can be incorporated by the Soil Conservation Service and can help to point out practices which benefit the farmer as well as reduce the potential for water quality degradation.

E. Artificial Phosphorus Abatement

No sanitary survey was conducted along the first tier homes surrounding Beaver Lake. At the time of our study the Town of Derry was in the process of sewering the lake shore region, and required hook-up by all first tier home owners. Phosphorus input to the nutrient budget from septic systems was estimated to be 25% of its predicted value prior to sewering for a period of time, to take into account residues from leachfields.

F. Recommendation Summary

The Southern N.H. Planning Commission put together a Water Resource Management and Protection Plan for the Town of Derry in 1989. In this plan they review the strengths and weaknesses of the towns zoning laws, list potential point and non-point threats, and make recommendations for strengthening the town's protection of its water resources. The following is taken from this plan.

1. Description of existing programs and policies

Local ordinances and regulations were reviewed for the purpose of identifying the elements of each which have the potential for impacting water quality and quantity. The results of this review are summarized as follows:

1. *The overlay wetlands conservation district provisions are designed to protect both water quality and quantity, by restricting development and land use activities which could contribute to the contamination of surface and ground water, and which could destroy the natural wetlands which provide flood protection, groundwater recharge, wildlife habitat, and the augmentation of stream flow during dry periods. These include protection from fertilizers, pesticides and herbicides.*

2. *Prime wetlands have been mapped, and restrictive provisions concerning land use activities in these areas have been adopted in accordance with the provisions of N.H. RSA 483-A:7.*

3. *Sanitary protection provisions regulate the design, placement and use of subsurface wastewater disposal systems; require specific setbacks from wetlands, including surface waters, swamps, bogs, and marshes; and prohibit discharges to other than approved sanitary systems.*

   The Town of Derry Sewer Ordinance requires that the owner of all houses, buildings or properties which are used for human occupancy, employment, recreation, or other purposes within the town, and abutting on any street, alley or right-of-way in which there is now *or may in the future be located a public sanitary sewer shall, at his or her expense, install suitable toilet facilities therein, and connect such facilities directly to the public sewer within ninety (90) days of the date of official notice to do so, provided that the public sewer is located within one hundred (100) feet of the property line.*

4. *High density residential developments must be connected to the municipal sewerage system. In addition, any use that will not be served by the municipal sewerage system must be located on a lot containing at least one-third more area than is required for a similar use which will be served by this system.*

5. *To help facilitate groundwater recharge, the maximum lot coverage allowed for multi-family housing development is twenty-five percent. Nonresidential land uses must maintain at least one-third of their respective lots in open space which cannot be used for parking or other activities.*

6. *The overlay floodplain district provisions, which meet the requirements of the National Flood Insurance Program, is another effective local mechanism to further enhance efforts to protect water quality in that they require new and replacement water supply and wastewater disposal systems (including on-site systems) to be located, designed and constructed in such a way that infiltration and operational impairment by 100-year flood events will be minimized and/or avoided.*

Earth Removal Ordinance

The excavation, grading, filling, or removal of earth, loam, topsoil, sand, gravel, clay or stone is regulated by permits issued by the Planning Board under the authority granted in N.H. RSA 155-E. Receipt of permits is conditioned upon the submission and approval of detailed excavation and site restoration plans for the protection of water supplies; the control of surface runoff; and the prevention of erosion and sedimentation.

Building Code

The BOCA Basic Building and Plumbing codes are administered by the Building Inspector to assure that the design and installation of plumbing systems, including sanitary facilities, water supplies and sewage disposal systems are such that their use will not impair public or private water supplies.

Subdivision Regulations

The Town of Derry subdivision regulations contain specific provisions which are intended for the protection and management of surface and groundwater resources. Included are the following:

1. *National Flood Insurance Program requirements to protect surface and groundwater.*

2. *Applications for proposed developments which will not be served by the municipal sewerage system must be accompanied by a report from the Health Officer, based on seepage and other tests that he may require, which indicate that the area of each lot is adequate to permit the installation of an individual subsurface wastewater disposal system.*

3. *Residential lots without public water and public sewer service must contain at least four times as much area as those having both services.*

4. *In all subdivisions, regardless of the type of land use activity proposed, if the development will not be served by the municipal sewerage system, the minimum size of the individual lots shall be based on the soil-type-to-lot-size relationship established by the Rockingham County Conservation District, with the soil type being determined on the basis of a high intensity soil survey.*

5. *Erosion and sedimentation controls in the form of allowed maximums for finished slopes and grades of drainage swales; and seeding and vegetation requirements for natural drainage ways.*

Site Plan Review Regulations

Under the town's site plan review regulations, the applicant for approval must demonstrate that the proposed development or activities will not:

1. *have an undue adverse impact on the absorptive capacity of wetlands;*

2. *increases flood water elevations;*

3. *have an adverse impact on water supply or adequate wastewater disposal;*

4. *cause the "after-development" intensity of storm water runoff or drainage from the tract to exceed that of "pre-development" conditions; or*

5. *harm any wildlife.*

Health Ordinance

The Town of Derry does not have a health ordinance per se; however, the zoning ordinance requires that specific standards relative to the location, construction and maintenance of sub-surface wastewater disposal systems, and the discharge of wastes and sewage, be adhered to. An appointed health officer is charged with the duty of enforcing these provisions, as well as other state regulations pertaining to water quality standards in accordance with N.H. RSA 147.

Summary

Although the provisions of Derry's ordinances and regulations which address specific water quality and quantity concerns have been somewhat described herein, the following listing summarizes which ordinances and/or regulations have the potential to positively impact specific concerns.

Concern	*Local Ordinance or Regulation*
1. *Erosion and sedimentation*	*- Earth Removal Ordinance; Subdivision Regulations*
2. *Surface water flows*	*- Zoning Ordinance; Earth Removal Ordinance; Subdivision Regulations; Site Plan Review Regulations*
3. *Groundwater recharge*	*- Zoning Ordinance; Site Plan Review Regulations*
4. *Management of existing and Potential Threats*	*- Zoning Ordinance; Subdivision Regulations; Site Plan Review Regulations; Building Code*
5. *Flood storage*	*- Zoning Ordinance; Subdivision Regulations; Site Plan Review Regulations*
6. *Encroachment on wetlands*	*- Zoning Ordinance; Subdivision Regulations; Site Plan Review Regulations; Earth Removal Ordinance*
7. *Nutrient levels*	*- Zoning Ordinance*
8. *Wildlife and fisheries*	*- Zoning Ordinance; Site Plan Review Regulations*

2. RECOMMENDATIONS FOR NEW OR REVISED POLICIES AND PROGRAMS

Nonregulatory Programs

The nonregulatory programs that are recommended to improve and/or enhance local water resources management and protection activities include the following:

1. *The Planning Board will request that they be kept informed by the Southern New Hampshire Planning Commission concerning the availability and the appropriateness for local use of new data and regional and state water resources programs.*

2. *Educational and informational programs should be used to provide the public with an understanding of the operation, proper use, and maintenance of septic systems and leach fields as a means of helping to prevent unnecessary system failures which could endanger surface and groundwater resources.*

3. *Users should be encouraged to institute no-cost water conservation measures in their homes and businesses. Appropriate suggestions could be described in inserts which could accompany billing statements.*

4. *The Conservation Commission, Fire Department, and the Public Works Department should be encouraged to co-sponsor periodic household hazardous waste collection programs.*

5. *The Derry Conservation Commission should continue to work with the landowners to obtain wetlands by gift, grant or bequest, and/or to obtain covenants or easements at no cost to the community to help assure wetlands protection; to prevent the development of wetland areas; and to maintain flowage. Such activities are authorized under N.H. RSA 36-A:4, but are subject to approval by the Mayor and Council.*

6. *The Derry Planning Board will work with their counterparts in the towns of Auburn, Chester, Sandown, Hampstead, Atkinson, Salem, Windham, and Londonderry to promote land use management concepts that are consistent with the mutually-beneficial need to protect common watersheds, wetlands, and aquifers.*

7. *As may be necessary in appropriate circumstances, the Conservation Commission should consider requesting that the capital improvements program include funding for the acquisition of land to protect surface and groundwater resources when non-fee land or easement acquisition programs are unsuccessful.*

8. *The Town of Derry Public Works Department should ensure that its salt spreaders, as well as those of any contractors that it hires, are properly calibrated to minimize the potential for the contamination of surface and groundwater resources while conducting winter road maintenance. The Department should also consider whether or not sand could be substituted for salt on those town road segments which overlay identified aquifers.*

   The Mayor and Council should make similar requests to the New Hampshire Department of Transportation.

9. *The Derry Conservation Commission should sponsor educational and informational programs utilizing the University of New Hampshire Cooperative Extension Service and the U.S. Department of Agriculture, Soil Conservation Service as a means of promoting the use of best management practices associated with the control of pesticide, herbicide and fertilizer applications.*

10. *The Public Works Department should recommend that funding be included in the capital improvements program to support the installation of public sewers to service developed areas where septic system failures have been a problem.*

11. *The Derry Conservation Commmission should be encouraged to continue its sub-committee work relative to the identification and acquisition of the most important conservation, recreation and natural resource areas.*

The costs of putting these non-regulatory programs in place are expected to be variable and, in some cases, not possible to estimate at this time. As an example, the Southern New Hampshire Planning Commission can generally provide technical assistance, on request, as part of Derry's membership in the Commission. It is possible that, depending on the nature of the request, that no additional cost would be required for this service.

Educational and water conservation programs could be relatively low-cost or no-cost activities that, with the cooperation of the Derry School District, could likely be incorporated into the existing curriculum. The preparation and printing of water bill inserts should be another relatively low-cost item. The value of the benefits that could be achieved through the implementation of these programs could greatly exceed their costs.

Household hazardous waste collection and disposal costs can be expected to be relatively high and, to some extent, will vary according to the amount of material collected. Information is available on representative costs incurred by communities that have been involved in this program. Advice indicates that such programs tend to be more feasible when conducted as a joint venture by two or three communities. Some financial assistance may be available from the Waste Management Division of the New Hampshire Department of Environmental Services.

It is likely that the only costs associated with wetlands protection efforts involving gifts, grants and bequests of land, and the establishment of covenants and easements would pertain to survey, legal and recording fees. The outright purchase of wetland areas would obviously entail substantially greater additional costs.

Capital expenditures for the installation of sanitary sewers, and for the acquisition of land and/or development rights for purposes of protecting water resources will be high.

Salt spreaders can be calibrated as part of routine maintenance at no additional cost to the town or the state.

Any effort worth pursuing will require the commitment of human resources; however, it is believed that these nonregulatory programs could be carried out by existing voluntary and paid manpower. It should not be necessary for the town to hire additional personnel to conduct or oversee any of these activities.

<u>*Regulatory Programs*</u>

The Town of Derry enforces a zoning ordinance, subdivision regulations, site plan review regulations, an earth removal ordinance, floodplain development regulations, a wetlands conservation district ordinance, a sewer use ordinance, and the BOCA building code, all of which contain varied provisions for water resource protection.

All options for regulatory programs required by the rules for Local Water Resource Management and Protection Plans were considered, and the following actions are recommended as means of improving local water resource management and protection mechanisms.

1. *The nonresidential site plan review regulations should be amended to require that all applicants identify on their plans the locations, type, contents, and capacities of all in-ground and above-ground petroleum and chemical storage tanks, regardless of their size, in order to maintain a current inventory of such facilities.*

2. *The building code ordinance should be amended to provide for the revision of the building permit application form so that the same information cited above can be obtained for those activities which might not be subject to the site plan review process.*

Since Derry has a town planner, the cost of preparing proposed amendments to the site plan review regulations and the building code ordinance should be minimal. If necessary, technical assistance services for such activities could likely be provided, on request, by the Southern New Hampshire Planning Commission. Some expense would be incurred by the town in complying with the requirements for the publication of notices announcing the public hearings that would have to be held on the proposals.

Since the goal of the surface and groundwater portions of this plan is to assure that local land use decisions resulting from this planning process are based upon the most comprehensive and reliable scientific and technical information available, it is important that all implementing ordinances and regulations should include (1) a process which allows applicants for local approvals to present documented scientific and technical information which differs from the information which was used to prepare this Plan; and (2) the implementing ordinances and regulations should also include mechanisms which will allow local decision makers to consider the scientific and technical information submitted by the applicants prior to making a final decision.

The Planning Board is aware that the New Hampshire Department of Environmental Services is in the process of updating water user information, and mapping and digitizing the locations of all water wells, underground storage tanks, etc. This information, while not currently available statewide, is expected to be available in the future. The Board will endeavor to obtain and consider such information in the course of conducting the next Master Plan update.

The Town of Derry has done much to ensure safekeeping of water resources. The Natural Resources Zoning, and specifically the Water Resources Conservation Zone ensure that these valuable assets will have protection in the future. However, more can still be done.

3. D.E.S. Recommendations

The following are our recommendations for protecting Beaver Lake:

a. Lake Protection District

We recommend that a Lake Protection District be set up by the Town of Derry. This District is defined as an environmentally sensitive area surrounding the lakes and ponds of Derry in which development activities must be closely regulated to preserve the lake quality. This protection district should also include each sub-drainage basin to the lake. Since land use in the lake's watershed is the key to nutrient and sedimentation rates to the lake, more effort must be devoted to this important element. The adoption of the State's Shoreland Protection Act as discussed earlier in this chapter would be a great benefit to protecting the town's waterbodies.

b. Education

The Town of Derry and the Beaver Lake Association should initiate an education program aimed at educating lake residents, transient lake recreationists and private/public beach users.

Given a choice and a better understanding of the consequences of their actions, most people will opt to improve their environment. If all residents of the Beaver Lake watershed could enjoy the benefits of a choice recreational facility, they would likely take a greater interest in protecting water quality.

The use of the local media to provide tips on lake protection can be a valuable source of information. Signs posted at public beaches and launches help educate the transient users on things they should not be doing while utilizing the waterbody.

The following is a list of practices that property owners and lake users should follow to help protect lake water quality.

a. Lawn fertilization has the potential to create excessive nutrient runoff to drainages and the ponds directly. The use of such fertilizers should be limited near any surface waters. Education of the public to the deleterious effects of fertilizers is recommend.

b. Leaf control is important in reducing the phosphorus load to a waterbody. All leaf and grass dumping or burning on the banks of the lake should be eliminated . The removal of vegetative material to an area away from the lake will reduce the phosphorus source.

c. Land clearing should be kept to a minimum and bare areas should be revegetated to minimize erosion into the waterbody. Maintain a buffer zone of natural vegetation along the shore to contain erosion and assimilate phosphorus.

d. Do not bathe, shampoo, or wash anything in the lake with soap or any detergent.

e. Do not urinate or defecate in the lake or pond, and don't allow domestic animals to do the same. Animals should not be housed near the lake where the phosphorus in their manure can be washed into the lake by runoff.

f. Waterfowl management should be practiced at Beaver Lake. Enough natural food substances exist around lakes and ponds to feed duck and geese populations. Property owners should discourage the feeding of waterfowl. Studies have shown that duck and goose excrement is very high in phosphorus and nitrogen concentrations.

The Town of Derry should encourage their elementary and secondary schools to participate in the Department of Environmental Services' Interactive Lake Ecology program. This program is designed to educate the young on principles of lake ecology and preservation of these resources, ensuring that the future residents of the area have the necessary education to be the safeguards of their water resouces.

c. Volunteer Monitoring

Volunteer Monitoring should be reinstated on an annual basis for Beaver Lake. It is important to continue gathering chemical and biological data and defining long term trends. It will also be interesting to determine lake quality trends in lake development or watershed development.

d. Education and Best Management Practices for Hobby Farms

An educational program should be made available on BMP's for those people in the watershed who practice animal husbandry or manage "hobby farms".

Hobby farms, with one or more animals, may have poor grazing practices, too many animals per acre, unrestricted access to streams, poor waste management practices and poorly drained soils. Such farms have limited space and capital with which to construct facilities for animal management. They have not traditionally been eligible for cost-sharing grants from federal or state programs.

Since small farms contribute to non-point sources of phosphorus and may even contribute more phosphorus than larger farms that practice BMP's, an educational program is needed on BMP's for waste and pasture management.

e. Best Management Practices for Silviculture

Silviculture activities in the Beaver Lake watershed must be strictly enforced and regulated. Frequent inspections of silviculture activities may detect a future water quality problem before it is too late for remedial action.

Forests or abandoned fields are the most common type of land-use cover in the Beaver Lake watershed. As such, there is potential for future water quality impacts due to silvicultural activities. Performance standards and plan review for silvicultural activities are regulated by the state through timber harvesting and water quality protection laws. Regulation prohibits the placement of slash and mill waste in or near waterways, and limits clear-cutting near great ponds and streams. These requirements may mitigate to some degree the water quality impacts associated with timber harvesting. More stringent local regulations could increase the setback requirements for disposal of slash.

A major cause of water quality degradation associated with forestry activities is soil erosion caused or aggravated by logging and skidder roads. Disruption of the vegetative cover, disturbance by heavy equipment, and the often steep slopes on which cutting is carried out, combine to create conditions favoring rapid and severe erosion. Where access to harvest areas involves crossing a waterway, eroded material can rapidly impact downsteram waterbodies. The New Hampshire Water Supply and Pollution Control Division responds to complaints of poor logging practices that impact water quality. Presently, the town is protected by the Earth Removal Ordinance (section II of town zoning ordinance, see Section 3 D, C and Appendix XI-4). This ordinance takes into account final slope and reseeding requirements. Further protection is provided by the Natural Resource Zoning (Section 7.1 Prime Wetlands and Prime Wetland buffer zones). This law regulates forestry and tree farming practices in wetlands and surrounding wetland buffer zones. However, the development of local forestry bylaws, under the administration of the Conservation Commission or Planning Board, would provide additional protection to the water resources in the Town of Derry.

f. Restricted and Permitted Land Use

Land use regulation is an alternative commonly recommended as a supplement to other watershed and in-lake management measures for control of eutrophication. A number of state and local regulations concerning land use activities are intended to protect surface and groundwater quality, or indirectly serve that function in addition to their intended purpose. Several factors must be weighed when considering a nutrient source control program which is based upon local regulation. To be effective, a control measure should meet three conditions. First, it must be aimed at sources which are controllable. Second, it must be workable and enforceable through the jurisdictional framework within which it is to be implemented. Third, it must be flexible enough to accomodate innovative development options of feasible engineering alternatives while discouraging other, perhaps deleterious, land use forms. Land use regulations typically serve to modify or limit non-point sources of pollutants in a watershed. Thus, the impact of existing regulations, or the effect of implementing new regulations, cannot be adequately determined.

Much of these land use regulations should be included in the shoreland protection ordinance.

1. Restricted Uses

Some land uses, by their nature, pose a threat to water quality by introducing or concentrating potential pollutants in the watershed.

Other uses such as sawmills, auto repair garages, riding stables, and storage and disposal of solid waste should be assessed. Surface stormwater drainage for subdivisions should not be allowed to drain directly into a waterbody. Any development should treat stormwater runoff in a way which is deemed acceptable by the Water Supply and Pollution Control Division. In granting exceptions for such uses, or others which could threaten ground or surface water quality, the Board of Adjustment should consider professional advisement on setting conditions and safeguards for water quality protection. Indirect restrictions of some land uses are provided by the Derry zoning bylaws, by listing only the uses permitted for each district.

2. Permitted Uses

The most effective method of guarding against negative water quality due to permitted uses is the setting of specific performance standards for certain activities. In the Beaver Lake watershed, the most pertinent land use activities may be forestry, agriculture, earth removal, and subdivision development. We have discussed in great detail that earth removal should be monitored and inspected on a frequent basis to guard against erosion of materials into any waterbody. Such activities are also governed by state statutes concerning earth removal: RSA-45-A:17 requires permits for construction, earth moving or other significant alteration of the terrain.

Subdivision regulations for Derry require that due regard be given the protection of brooks, streams and other waterbodies. Required improvements for subdivision developments should include stormwater drainage systems which assure minimal changes in the quantity and quality of runoff. An additional recommendation would be to require that comprehensive soil erosion and sedimentation control plans are part of each subdivision filing.

g. Stormwater Runoff Management

The stormwater runoff plan for all roads surrounding Beaver Lake should be examined. Town engineers should map out all direct discharges of stormwater runoff into Beaver Lake. A best management plan should be designed to treat or reduce the chemical pollutants that enter a lake via stormwater runoff. Matching funds may be available to install swales, retention basins or to incorporate other means of stormwater control.

G. Project Schedule and Monitoring Program

Phosphorus inactivation of the Beaver Lake bottom sediments, combined with management of Manter Brook and management of stormwater runoff, comprise the basis of the Beaver Lake restoration program.

Table XI-8 provides a suggested and preliminary project implementation schedule. A preliminary monitoring program and schedule, designed to gauge the effectiveness of the different restoration strategies is shown in Table XI-9. Table XI-10 is a summary table of DES recommendations.

The extent to which the restoration/management strategies developed for Beaver Lake are eventually implemented will largely be dependent on the continued availability of local, state and federal funds. The 1993 Clean Lakes Budget has only five million dollars available nationwide. This money will be allocated for both Phase I and Phase II Clean Lakes Programs. Assuming through a combination of federal, state and local sources, sufficient funds will be made available, watershed management implementation is proposed to begin during the fall of 1993. Watershed management techniques, such as phosphorus reduction in Manter Brook utilizing a wet pond and stormwater management, are dependent on non-point source (section 319 of the Clean Water Act) funding.

Phosphorus inactivation of the sediments of Beaver Lake to limit internal phosphorus loading will not begin until the watershed management phase is completed. If Best Management Practices have been completed by October of 1994, the phosphorus inactivation phase will begin in June of 1995.

Recommendations like: adopting a Shoreland Protection ordinance; creating an education program for lake users and school aged children; adopting BMP's for hobby farms, agriculture and silviculture; and continuing with a volunteer monitoring program can all begin immediately. Lake quality and biological monitoring of Beaver Lake and Manter Brook should coincide with watershed management activities. A three year monitoring program will be initiated on Manter Brook to determine if the proposed wet pond has reduced the phosphorus

Table XI-8

Preliminary Project Implementation Schedule

Task Year	1993				1994				1995			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4
Review and Possible Revision of Derry Ordinances												
* Adopt Shoreland Protection Ordinance	★	★	●	●								
* Adopt B.M.P. Ordinances For Silviculture, Agriculture, and Hobby Farms	★	★	●	●								
Watershed												
* 319 Proposal	△	△	△									
* Manter Brook Wet Pond Construction				★	★	●	●	●				
*Stormwater Management				★	★	●	●	●				
In-lake												
* 314 Proposal					△	△	△					
*Dose and Ratio Determination For Aluminum						●	●	●	●			
* Sediment Inactivation Experiments						●	●	●	●			
* Phosphorus Inactivation										●	●	
Education												
* School Systems	★	★	●	●								
* Lake Users	★	★	●	●								

Key

△	Grant Application Submittal, Review, Award and Procure Local Match
★	Evaluation \ Design
●	Implementation

Table XI-9 Preliminary Monitoring Program and Schedule

Task / Year	1993				1994				1995				1996				1997			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
WATER QUALITY																				
* Manter Brook Wet Pond			⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
* Stormwater Runoff							+	+	+	+	+	+	+	+	+	+	+	+	+	+
* Beaver Lake (DES and Volunteer Monitors)			+				+			⊕	⊕	⊕	⊕	⊕	⊕				+	
BIOLOGIC																				
* Manter Pond											A				A				A	
* In-Lake		(A-D)				(A-D)				⊕	⊕	⊕	⊕	⊕	⊕			(A-D)		
HYDROLOGIC												(A-D)◇								
* Manter Brook			⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
* Stormwater Runoff							+	+			+	+			+	+				

Key 1

⊕	Continuous Monthly Or Bi-Weekly Sampling
+	Single Sampling Round

Key 2

A - Macrophyton
B - Plankton
C - Macroinvertebrates
D - Fish

Table XI-10

DES Recommendations Summary for Beaver Lake

ZONING AMENDMENTS

-Lake Protection District (Adoption of Shoreland Protection Ordinance)

- Restricted Uses
- Permitted Uses

-Stormwater Runoff Management Plans

EDUCATION

-Local Education - Lake Related

- Lake Residents
- Transient Users

-Local Education - Watershed Concerns

- B.M.P.'s for Hobby Farms
- B.M.P.'s for Silviculture

-Interactive Lake Ecology Program

-Volunteer Lake Assessment Program

LAKE RESTORATION

-Stormwater Management

-Wet Pond Construction

-Sediment Phosphorus Inactivation

load to the lake. Water quality and hydrologic monitoring of the wet pond is an integral component of the overall program to better define the relationship between phosphorus reductions and the process of achieving it, be it sedimentation, vegetative assimilation or adsorption. Programs will also be set up to monitor the efficiency of the proposed stormwater management practices to reduce sedimentation and phosphorus to the lake. Beaver Lake will be monitored by both aquatic biologists from DES and by Volunteer Monitors from the Lake Association. The Beaver Lake Volunteer Monitoring Program will be initiated before Watershed Management Construction occurs and will continue for a three year period. Monthly or bi-weekly sampling of Beaver Lake and Manter Brook is proposed through September of 1996 (Table XI-9) to ascertain any change in trophic state resulting from the inactivation treatment and the watershed management practices. Depth integrated sampling within the lake and analyses for phosphorus and other lake quality and biologic parameters will be continued. A summer vascular plant (macrophyton) survey of the lake and sampling of the macroinvertebrate and fish communities should also be performed. Rooted submergent macrophytes, although presently abundant throughout the lake, may extend their distribution into deeper waters as lake clarity improves. Benthic macroinvertebrates are useful indicators to assess any long-term toxic effects of the aluminum treatments. Fish communities should be tested for whole tissue aluminum before and after treatment.

H. Phase II Implementation Budget

1. 1993 Budget

Engineering designs and premonitoring

Contractual		
Engineering costs		$2,000
Personnel		
Environmental Technician I	6 months	$7,615
Benefits		$2,132
Indirect costs		$ 487

Administrative support	$ 500
Travel	$1,000
Laboratory Services	$ 700
Supplies	$1,000
Equipment	$1,000
Audit	$ 20
Total cost	$16,454

2. 1994 Budget

Contractual		
Construction costs (wet pond)		$ 8,000
Construction costs (stormwater Best Management Practices)		$12,000
Personnel		
Environmentalist I	12 months	$20,066
Laborer	10 weeks	$ 2,750
Benefits		$ 5,829
Indirect costs		$ 1,432
Administrative support		$ 1,432
Travel		$ 2,000
Laboratory Services		$ 1,360
Supplies		$ 2,000
Equipment		$ 1,000
Audit		$ 60
	Total cost	$57,929

3. 1995 Budget

Contractual		
Sediment Phosphorus Inactivation		$40,000
Personnel		
Environmentalist I	12 months	$20,924
Laborer	10 weeks	$ 2,750
Benefits		$ 6,069
Indirect costs		$ 1,487
Administrative support		$ 1,487

Travel		$ 2,000
Laboratory Services		$ 1,730
Supplies		$ 2,000
Equipment		$ 5,000
Audit		$ 80
	Total cost	$80,777

4. 1996 Budget

Personnel		
Environmentalist I	12 months	$22,000
Laborer	10 weeks	$ 3,000
Benefits		$ 6,460
Indirect costs		$ 1,573
Administrative support		$ 1,573
GIS Services		$ 1,573
Travel		$ 2,000
Laboratory Services		$ 1,700
Supplies		$ 2,000
Equipment		$ 1,000
Audit		$ 40
	Total cost	$42,919

5. 1997 Budget

Personnel		
Environmentalist I	12 months	$23,000
Laborer	10 weeks	$ 3,000
Benefits		$ 6,740
Indirect costs		$ 1,637
Administrative support		$ 1,637
GIS Services		$ 1,637
Travel		$ 2,000
Laboratory Services		$ 1,700
Supplies		$ 2,000
Equipment		$ 1,000
Audit		$ 45
	Total cost	$44,396

BIBLIOGRAPHY

American Public Health Association, 1992. Standard Methods for the Examination of Water and Wastewater, 18th Edition.

Bentley, 1969.

Biggs, B.F., 1989, Biomonitoring of Organic Pollution Using Periphyton, South Branch, Canterbury, New Zealand. New Zealand Journal of Marine and Freshwater Research, 1989, Vol. 23: 263-274.

Billings, M., 1934. Paleozoic Age Rocks of Central New Hampshire. Science N.S., 79:55-56.

Billings, M.P., 1956, Geology of New Hampshire, Part II. Bedrock Geology. N.H. State Planning and Development Commission.

Born, J.S. and D. Yanggen, 1972. Understanding Lakes and Lake Problems. University of Wisconsin Extension, Publication G2411.

Brezonik, P. 1973. Nitrogen Sources and Cycling in Natural Waters. Office of Research and Monitoring, USEPA, 66013-73-002. 167 pp.

Buergel, P. and R. Soltero, 1983. The Distribution and Accumulation of Aluminum in Rainbow Trout Following a Whole-Lake Alum Treatment. Journal of Freshwater Ecology, 2(1):37-43.

Burns, N.M., 1970. Temperature, Oxygen and Nutrient Distribution Patterns in Lake Erie, 1970. J. Fish, Res. Board Can., 33:485-511.

Carlson, R.E., 1977. Trophic State Index for Lakes. Limnol. Oceanogr., 22:361-369.

Collins, G.B., and C.I. Weber, 1978. Phytoperiphyton (Algae) as Indicators of Water Quality, Trans. Amer. Micros. Soc., 97(1): 36-43. 1978.

Connecticut D.E.P. Personal Communication

Connor, J.N., 1979. The Significance of Seepage to the Water and Nutrient Budgets of Lake Washington. M.S. Thesis. Florida Institute of Technology, Melbourne, Florida.

Connor, J.N. and T.V. Belanger, 1981. Groundwater Seepage in Lake Washington and the Upper St. John's River Basin, Florida. Water Resources Bulletin, 17(5):799-805.

Connor, J.N. and G. N. Smith, 1983. Kezar Lake Diagnostic/Feasibility Study; Final Report. New Hampshire Water Supply and Pollution Control, Staff Report No. 35.

Connor, J.N. and M.R. Martin, 1986. Wetlands Management and First Year Response of a Lake to Hypolimnetic Aluminum Salts Injection. New Hampshire Water Supply and Pollution Control, Staff Report No. 144.

Connor, J.N. and G. N. Smith, 1986. An Efficient Method of Applying Aluminum Salts for Sediment Phosphorus Inactivation on Lake. American Water Resources Bulletin, 22:661-664.

Connor, J.N. and M.R. Martin 1988. French and Keyser Ponds Diagnostic and Feasibility Study. New Hampshire Water Supply and Pollution Control Division. Staff Report No. 157.

Connor, J.N. and M.R. Martin, 1989. An Assessment of Sediment Phosphorus Inactivation, Kezar Lake, New Hampshire. Water Resource Bulletin, 25(4):845-853.

Connor, J.N. and D.J. Dubis 1990. Webster Lake Diagnostic/Feasibility Study. New Hampshire Water Supply and Pollution Control Division. Staff Report No. 90-6.

Connor, J.N., P.M. McCarthy and M. O'Loan. 1992. Mendums Pond Diagnostic/ Feasibility Study. New Hampshire Water Supply and Pollution Control Division. Staff Report No. 92-4.

Cooke, G.D. 1979. Evaluation of Aluminum Sulfate for Phosphorus Control in Eutrophic Lakes. OWRT Proj. No. A053-0410. Final Report. Ohio Water Resources Center. Columbus, Ohio.

Cooke, G.D., M.R. McComas, D.W. Waller and R.H. Kennedy, 1977. The Occurrence of Internal phosphorus Loading in Two Small, Eutrophic, Glacial Lakes in Northeastern Ohio. Hydrobiol., 56:129-135.

Cooke, G.D., R.T. Heath, R.H. Kennedy and N.R. McComas, 1978. Effects of Diversion and Alum Application on Two Eutrophic Lakes. EPA-600/3-78-033.

Cooke, G.D. and R.H. Kennedy, 1980. Precipitation and Inactivation of Phosphorus as a Lake Restoration Technique. EPA, Ecological Research Series, EPA-600/3-81/012.

Cooke, G.D., R.T. Heath, R.H. Kennedy and N.R. McComas, 1982. Change in Lake Trophic State and Internal Phosphorus Release After Aluminum Sulfate Application. Water Resource Bulletin, 18(4):699-705.

Cooke, G.D., E.B. Welch, S.A. Peterson and P.R. Newroth, 1986. Lake and Reservoir Restoration. Butterworths Pub., 392 pgs.

Cowing, D.J. and D. Lash, 1979. Characteristics of Lakes, Ponds and Reservoirs of New Hampshire, with a Bibliography. U.S. G. S., Open File Report 75-490, 182 pgs.

Cummings, O.R. 1990. Trolleys to Beaver Lake, A History of the Chester and Derry Railroad Association 1891-1928.

Dennis, J., 1986. Lake and Reservoir Management, Volume II. North American Lake Management Society.

Dennis, J. 1988. Lake and Reservoir Management, Volume IV. North American LakeManagement Society.

Derry Historical Research Committee. 1977. From Turnpike to Interstate, The 150 Years of Derry, NH. 1977. Phoenix Publishing, Canaan,N.H.

Dillon, P.J. and F.H. Rigler, 1974. The Phosphorus - Chlorophyll Relationship in Lakes. Limnol. Oceangr., 18(5):767-773.

Dillon, 1975.

Dominie, D. 1980. Hypolimnetic Aluminum Treatment of Softwater Annabessacook Lake. EPA 440/5-81-010.

Domogalia, B.P., E.B. Fred and W.A. Peterson. 1926. Seasonal Variation in the Ammonia and Nitrate Contents of Lake Waters. Journal of the American Water Works Association. 15:369-385.

Downing, W.J. and J.J. Peterka, 1978. Relationship of Rainfall and Lake Groundwater Seepage. Limnol. Oceanogr., 23(4):821-825.

Driscoll, E.D. 1983b. Performance of Detention Basins for Control of Urban Runoff Quality. University of Kentucky. Lexington, Kentucky. 40 pp.

Edmondson, W.T., 1972. Nutrients and Phytoplankton in Lake Washington. Limnol. Oceanogr., 5 Proc. Symp., Vol. 1:172-193.

Eisenreich, S.J., D.E. Armstrong and R.F. Harris, 1977. A Chemical Investigation of Phosphorus Removal in Lakes by Aluminum Hydroxide. University of Wisconsin, Madison, Wisconsin Water Resources Center, Technical Report No. 77-02.

Elder, W., 1989. Soil Conservation Services Report.

Estabrook, R.H. and R.E. Towne, 1982. Northwood Lake Diagnostic/Feasibility Study Final Report. New Hampshire Water Supply and Pollution Control Commission, Staff Report No. 131. 281 pp.

Everhart, W.H. and R.A. Freeman, 1973. Effects of Chemical Variations in Aquatic Environments, Vol. II. Toxic Effects of Aqueous Aluminum to Rainbow Trout. EPA-R3-73-011b.

Fairfax County Dept. of Environmental Management. (FCDEM) 1980. Design Manual for BMP Facilities.

Fellows, C.A., 1978. The Significance of Seepage in the Water and Nutrient Budgets of Selected Florida Lakes. A Thesis Presented to the Graduate Council of the University of Florida, Gainesville, Fla. 140 pp.

Feth, J.S. 1966. Nitrogen Compounds in Natural Water. A Review. Journal of Water Resources Research. 2:41-58.

Flanders, R.A., 1986. Final Report, Baboosic Lake Study. New Hampshire Water Supply and Pollution Control, Staff Report No. 148.

Francis, S.F., 1989. Planning and Zoning Manual for New Hampshire Communities 125 pp.

Frink, C.R., 1967. Nutrient Budget: Rational Analysis of Eutrophication in a Connecticut Lake. Environmental Science Technology, 1(5):425-428.

Frost, T.P., R.E. Towne, H.J. Turner and R.H. Estabrook. 1976. Algae Control by Mixing: Kezar Lake-Sutton, N.H. Staff Report No. 79. N.H. Water Supply and Pollution Control Commission. 173 pp.

Gasperino, A.F. and R.A. Soltero, 1978. Restoration of Medical Lake: Engineering Design and Preliminary Findings. BN-SA-807. Battelle Northwest, Richland, Washington.

Heath, R.T. and G.D. Cooke, 1975. The Significance of Alkaline Phosphatase in a Eutrophic Lake.

Historical Booklet Committee, Derry, N.H. 1969. Glimpses of Derry, N.H. 1719-1969. Ed Hatch, Printer, Derry, N.H.

HSU, 1976.

Hoover, E.E., 1938. Biological Survey of Merrimack Watershed, Survey Report No. 3, New Hampshire Fish and Game Department.

Iskander K and D.R. Keeney. 1974. Concentration of Heavy Metals in Sediment Cores from Selected Wisconsin Lakes. Environmental Science and Technology Vol. 8, #2, pp 165-170.

Jacoby, J.M., E.B. Welch and J.P. Michaud, 1982. Control of Internal Phosphorus Loading in a Shallow Lake by Drawdown and Alum. Conference of North American Lake Management Society, Vancouver, B.C.

Jones, J.R. and R.W. Backman, 1976. Prediction of Phosphorus and Chlorophyll Levels in Lakes. J. of Water Pollution Control Feder., 48(8):2176-2182.

Jones, R.A. and G. F. Lee, 1977. Septic Tank Disposal Systems as Phosphorus Sources for Surface Waters. EPA 600/3-77/129, 62 pgs.

Keeney, D.R. 1972. The Fate of Nitrogen in Aquatic Ecosystems. University of Wisconsin Water Resources Center Literature Review No. 3. 59 pp.

Kemp, 1979.

Kennedy, R.N., 1978. Nutrient Inactivation With Aluminum Sulfate as a Lake Restoration Technique. Ph.D. Dissertation, Kent State University.

Kennedy, R.H. and G. D. Cooke. 1974. Phosphorus Inactivation in a Eutrophic Lake by Aluminum Sulfate Application: A Preliminary Report of Laboratory and Field Experiments. Conference on Lake Protection and Management, Madison, Wisc.

Kennedy, R.H. and G.D. Cooke, 1980. Aluminum Sulfate Dose Determination and Application Techniques. In Restoration of Lakes and Inland Waters, EPA-400/5-81-010, 405-411

Knox, C.E. and T.J. Nordenson. 1955. Average Annual Runoff and Precipitation in the New England - New York Area. Hydrologic Investigations Atlas HA-7. U.S. Geological Survey, Washington, D.C.

Larson, D.P., K.W. Malueg, D.W. Schults and R.M. Brice, 1975. Response of Shagawa Lake, Minnesota, USA to Point Source Phosphorus Reduction. Vehr. Int. Ver. Limnol., 19:884-892.

Lee, D.R., 1972. Septic Tank Nutrients in Groundwater Entering Lake Sallie, MN. Masters Thesis, Univ. of North Dakota, 96 pgs.

Lee, D.R., 1977. A Device for Measuring Seepage Flux in Lakes and Estuaries. Limnol. Oceanogr., 22:140-147.

Lee, G.F. 1970. Factors Affecting the Transfer of Materials Between Water and Sediments. Literature Review #1 Eutrophication Information Program, University of Wisconsin, Madison. 50 pp.

Lee, G.F., E. Bentley, and R. Amundson. 1975. Effect of Marshes on Water Quality. pp. 105-127 In: A.D. Haster, ed., Coupling of Land and Water Systems. Spring-Verlag, N.Y.

Liaw, W.K. and H.R. MacCrimmon, 1978. Assessing Changes in Biomass of Riverbed Periphyton. Int. Revue Ges. Hydrobiol. 63, 2 155-171.

Likens, G.E. and O.L. Loucks, 1978. Analysis of Five North American Lake Ecosystems. Verh. Inter. Ver. Limnol. 20:568-573.

Lorenzen, M. and A. Fast. 1977. A Guide to Aeration/Circulation Techniques for Lake Management. EPA-600/3-77-044.

Ludium (75)

Lyons, J.B., W.A. Bothner, R.H. Moench and J.B. Thompson Jr., eds., 1986. Interim Geologic Map of New Hampshire. New Hampshire Department of Environmental Services. 86-1.

Madden, Carol. Derry Recreation, Personal Communication

Manchester Water Works, Personal Communication.

Martin, M.R. 1986. Glitchware In-house Software.

Martin, M. and D.R. Goff. 1972. Contribution from the Department of Limnology. Number 2, The Role of Nitrogen in the Aquatic Environment. Academy of Natural Sciences of Philadelphia. Philadelphia, Pa. 46 pp.

Maryland National Capital Park and Planning Commission (MNCPPC). - Montgomery County, 1984. Design Guidelines for Stormwater Management Facilities in Montgomery Parks. Dept. of Parks. Silver Spring, Maryland.

Maryland Water Resources Administration (Md WRA). 1986b. Minimum Water Quality and Planning Guidelines for Infiltration Practices. Maryland Dept. of National Resources, Annapolis, Maryland. 52 pp.

McBride, M.S. and H.O. Pfannkuch, 1975. The Distribution of Seepage Within Lakebeds. J. of Resources of U.S. Geological Surveys, 3:505-512.

McComas, M.R., 1977. State of the Art Measuring Groundwater Flow to Lakes. Presented at the Conference on Lake Management, Univ. of Wisconsin, April 1977.

Metropolitan Washington Council of Governments (MWCOG). 1983a. An Evaluation of the Costs of Stormwater Management Pond Construction and Maintenance Prepared for USEPA Nationwide Urban Runoff Program. 123 pp.

Montgomery County Dept. of Environmental Protection (MCDEP). 1984a. Stormwater Management Pond Design Review Checklist. Stormwater Management Division. Rockville, MD. 6 pp.

Munn, M.D., L.L. Osborne and J.J. Wiley, 1989. Factors Influencing Periphyton Growth in Agricultural Streams of Central Illinois. Hydrobiologia 174:89-87.

Narf, R.P., 1978. An Evaluation of Past Aluminum Sulfate Lake Treatments: Present Sediment Aluminum Concentrations and Benthic Insect Renewal. Wisconsin Department of Natural Resources, Madison, Wisconsin.

Narf, R.P., 1981. Influence of Lake Benthos on Inorganic Phosphate Translocation from Untreated and Aluminum Treated Lake Sediments. Report to the Office of Inland Lake Renewal, Wisconsin Department of Natural Resources.

New Hampshire Fish and Game. 1970. Biological Survey of the Lakes and Ponds in Cheshire, Hillsborough and Rockingham Counties. Survey Report No. 8C- State of New Hampshire. 219 pp.

New Hampshire Fish and Game. 1985. Annual Report, Division of Inland and Marine Fisheries. State of New Hampshire. 182 pp.

New Hampshire Site Planning Project, 1964. New Hampshire Public Water Bodies and Public Access Points. Report No. 4, State of New Hampshire. 100 pgs.

New Hampshire Water Supply and Pollution Control Commission. 1975. Nutrient Removal Effectiveness of A Septic Tank-Leaching Field System. Staff Report No. 65. State of New Hampshire. 145 pp.

N.H. Water Supply and Pollution Control Commission, 1979. Soil Manual for Site Evaluations in New Hampshire.

N.H. Water Supply and Pollution Control Commission, 1985. New Hampshire Lakes and Ponds Inventory, Volume II. Staff Report No. 133. 452 pp.

N.H. Water Supply and Pollution Control Commission, 1987. New Hampshire Lakes and Ponds Inventory, Volume III. Staff Report No. 153. 359 pp.

NOAA Atlas 1979.

Northern Virginia Planning District Commission (NUPDC). 1987. BMP Handbook for the Occaquan Basin.

Nylander, R.A. & R. P. Carter, P.E. April, 1990. State of New Hampshire Department of Environmental Services Surface Water Quality Regulations.

Occaquan Watershed Monitoring Laboratory (OWML). 1983. Final Contract Report: Washington Area NURP Project. Manassas, Virginia. 450 pp.

Olem, H. and G. Flock, eds. 1990. The Lake and Reservoir Restoration Guidance Manual. 2nd Edition. EPA-440/4-90-006. 326 pp.

Pastorak, R.A., T.C. Ginn and M.W. Lorenzen, 1981. Evaluation of Aeration, Circulation as a Lake Restoration Technique. EPA-600/3-81/014.

Peterson, S.A. 1981. Sediment Removals A Lake Restoration Technique, EPA-600/13-81-013.

Peterson, J.O., J.J. Wall, T.L. Wirth and S.M. Born, 1973. Eutrophication Control: Nutrient Inactivation by Chemical Precipitation at Horseshoe Lake, Wisconsin. Tech. Bull. No. 62, Wisconsin Department of Natural Resources, Madison, Wisconsin.

Peterson, S.A., W.D. Sanville, F.S. Stay and C.F. Powers. 1974. Nutrient Inactivation as a Lake Restoration Procedure-Laboratory Investigations. EPA-660/3-74-032.

Peterson, S.A., W.D. Sanville, F.S. Stay and C.F. Powers. 1976. Laboratory Evaluation of Nutrient Inactivation Compounds for Lake Restoration. J. Wat. Poll. Cont. Fed. 48:817-831.

Peterson, N.K. and S.A.L. Pilgrim, 1979. Soils of New Hampshire. New Hampshire Agriculture Experiment Station, University of New Hampshire and Soil Conservation Service, United States Department of Agriculture. Research Report No. 79.

Public Technology, Inc. 1977. Land Management: A Technical Report for State and Local Governments. Washington, D.C.

Recht, H.L. and M. Ghassemi. 1970. Kinetics and Mechanism of Precipitation and Nature of the Precipitate Obtained in Phosphate Removal from Waste-water Using Aluminum (III) and Iron (III) Salts. Wat. Poll. Cont. Res. Ser. 17010 EKI. 77pp.

Reckhow, K.H., M.N. Beaulac and J.T. Simpson, 1980. Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. EPA-440/5-80-011.

Reekie, F. Background to Environmental Planning. 1975. Fletcher & Son Ltd. Great Britain p 135.

Richardson, C.J. 1988. Freshwater Wetlands: Transformers, Filters, or Sinks? FOREM. 11(2):3-9.

Ripl, W., 1976. Biochemical Oxidation of Polluted Lake Sediments with Nitrat: A New Restoration Method. Ambio 5:132-135.

Sakamoto, M. 1966. Primary Production by Phytoplankton Community in Some Japanese Lakes and its Dependence on Lake Depth. Arch. Hydrobiol. 62:1-28.

Scalf, M.R., W.J. Dunlap and J.F. Kreissl, 1977. Environmental Effects of Septic Tank Systems. EPA-600/3-77-096.

Schloss, J.A. 1988. Derry Lakes and Streams, Freshwater Biology Group (FBG) and Lay Lakes Monitoring Program, University of New Hampshire Durham.

Schroeder, D.C., 1979. Phosphorus Export from Rural Maine Watersheds. Land and Water Resources Center, Univ. Maine Orono, 62-76.

Schueler, T.R. 1987. Controlling Urban Ruinoff: A Practical Manual for Planning and Designing Urban BMPs. Washington Metropolitan Water Resources Planning Board.

Shapiro, J., V. LaMarra and M. Lynch, 1975. Biomanipulation: An Ecosystem Approach to Lake Restoration. pgs. 85-95. In Symposium on Water Quality Management and Biological Control, University of Florida, Gainsville, P.C. Bregonik and J.L. Fox eds.

Snow, P.D. and F.A. DiGiano, 1976. Mathematical Modeling of Phosphorus Exchange Between Sediments and Overlying Water on Shallow Eutrophic Lakes. Division of Water Pollution Control. Massachusetts Water Resources Commission, No. MDWPC 76-10.

Southern NH Planning Commission. 1989. Water Resource Management and Protection Plan, Town of Derry, New Hampshire. Office of State Planning.

Sriramadas, A. 1966. The Geology of the Manchester Quadrangle, New Hampshire, Bulletin No. 2. N.H. Dept. of Resources and Economic Development.

Stumm, W. and J.J. Morgan, 1981. Aquatic Chemistry. Wiley Interscience Pub. 779 pgs.

Taylor, W.D., S.C. Hern, L.R. Williams, V.W. Lankon, M.K. Moris and F.A. Morris. 1979. Phytoplankton Water Quality Relationships in U.S. Lakes, Part VI: The Common Phytoplankton Genera from Eastern and Southeastern Lakes. Working Paper No 710. National Eutrophication Survey Office of Research and Development, U.S. E.P.A.

Towne R.E., 1970. Algae Control by Mixing. New Hampshire Water Supply and Pollution Control Commission, Staff Report No. 58.

Towne, R.E. and R.H. Estabrook, 1981. Classification and Priority Listing of New Hampshire Lakes, Volume 1. New Hampshire Water Supply and Pollution Control Commission, Staff Report No. 121. 426 pp.

Tri-County Regional Planning Commission. 1983. Evaluation of Urban Stormwater Runoff and Management Practices, Lansing, Michigan. Final Report to US EPA 35 pp.

United States Department of Agriculture SCS, Personal Communication.

United States Department of Commerce, NOAA National Weather Service. Station Numbers 14745, Concord, N.H. and 27-5211-2, Manchester, N.H.

U.S. Environmental Protection Agency. 1983. Results of the Nationwide Urban Runoff Program. Vol I. Final Report. Washington, D.C. 159 pp.

United States Environmental Protection Agency. Rev 1983. Methods for the Chemical Analysis of Water and Wastes. Washington, D.C. 600/4-79-020.

United States Environmental Protection Agency. 1986. Characteristics of Lakes in the Eastern United States. VOlume III. Data Compendium of Site Characteristics and Chemical Variables. EPA/600/4-86/1007C.

U. S. Environmental Protection Agency. 1986. Methodology for Analysis of Retention Basins for Control of Urban Runoff Quality. Nonpoint Source Branch. Washington, D.C. EPA-440-5-87-001.

United States Environmental Protection Agency. 1990. Lake & Reservoir Restoration Guidance Manual Second Edition. Washington, D.C. EPA-440/4-90-006. 326 pp.

Vander Voet, D. 1959. Soil Survey of Rockingham County, N.H. Series 1954, No. 5. USDOA, SCS in Cooperation with the N.H. Agriculture Experiment Station.

Vollenweider, R.A., 1975. Input-output Models, with Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrologic, 37:53-84.

Wallace, R.A., J.L. King and G.P. Sanders. 1981. Biology, The Science of Life. Scott, Foresman and Company, Glenview Ill.

Wanielista, M.P., 1978. Stormwater Management Quantity and Quality. Ann Arbor Science Pub.

Wetzel, R.G. 1975, 1983. Limnology. Holt, Rinehart and Winston, Inc. FL. 767 pp.

Wiegand et al. 1986. Cost of Urban Runoff Controls. American Society of Civil Engineers. New York, N.Y. pp 366-381.

Yousef, Y.A., W.M. McLellon and H.H. Zebuth. 1979. Changes in Phosphorus Concentrations Due to Mixing By Motorboats in Shallow Lakes. Report Presented to the North American Lake Management Committee

APPENDIX II-1

APPENDIX II-1

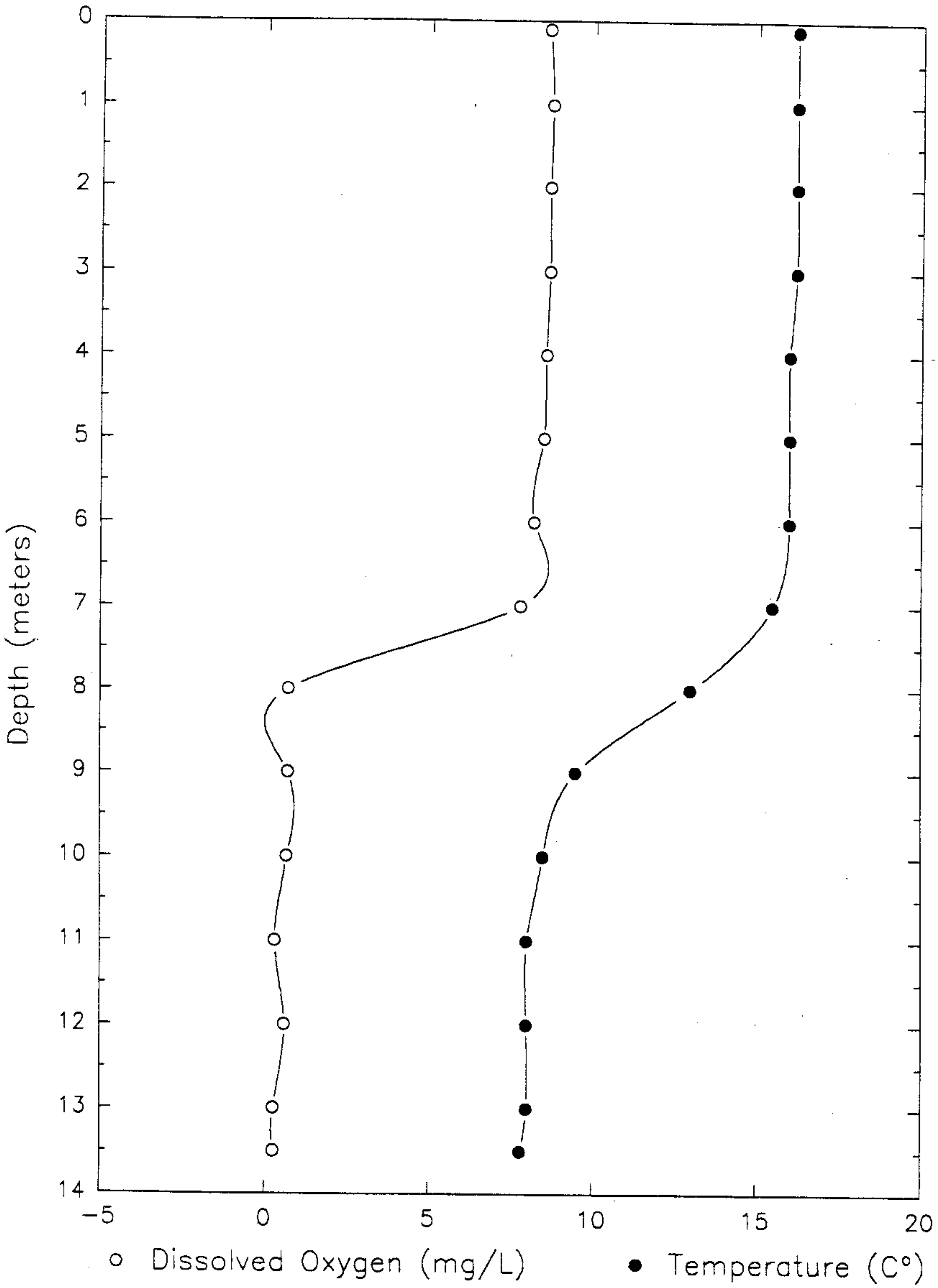
Historical Population figures for Derry

Londonderry	
1767	2389
1773	2471
1775	2590
1790	2622
1800	2650
1810	2766
1820	3127

Derry	
1830	2176
1840	2034
1850	1850
1860	1995
1870	1809
1880	2140
1890	2604
1900	3583
1910	5123
1920	5382
1930	5131
1940	5400
1950	5826
1956	5344
1960	6987
1965	9388
1970	11712
1975	15828
1980	18875
1985	22830
1990	29603

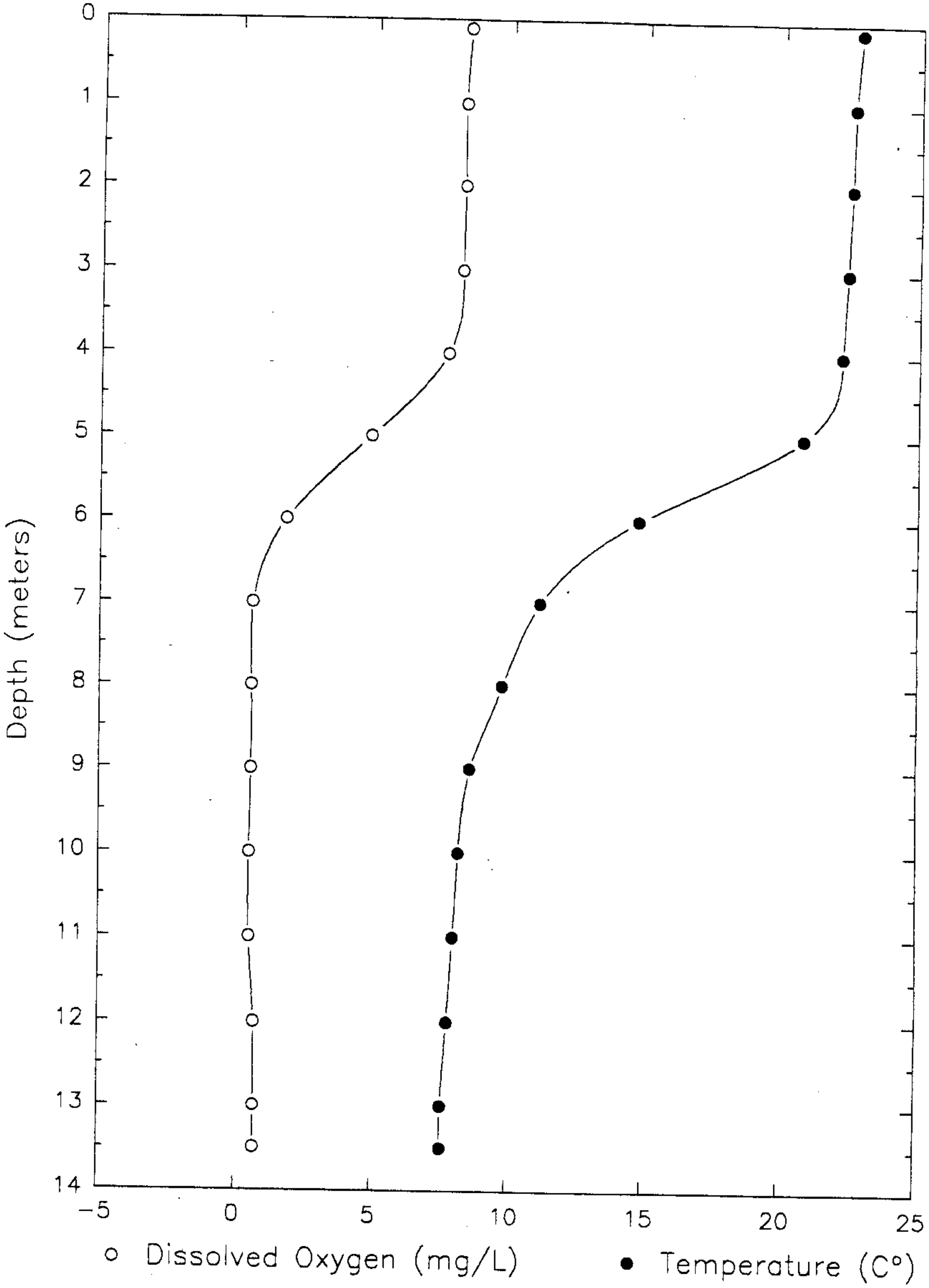
APPENDIX V-1

Beaver Lake
10/05/90



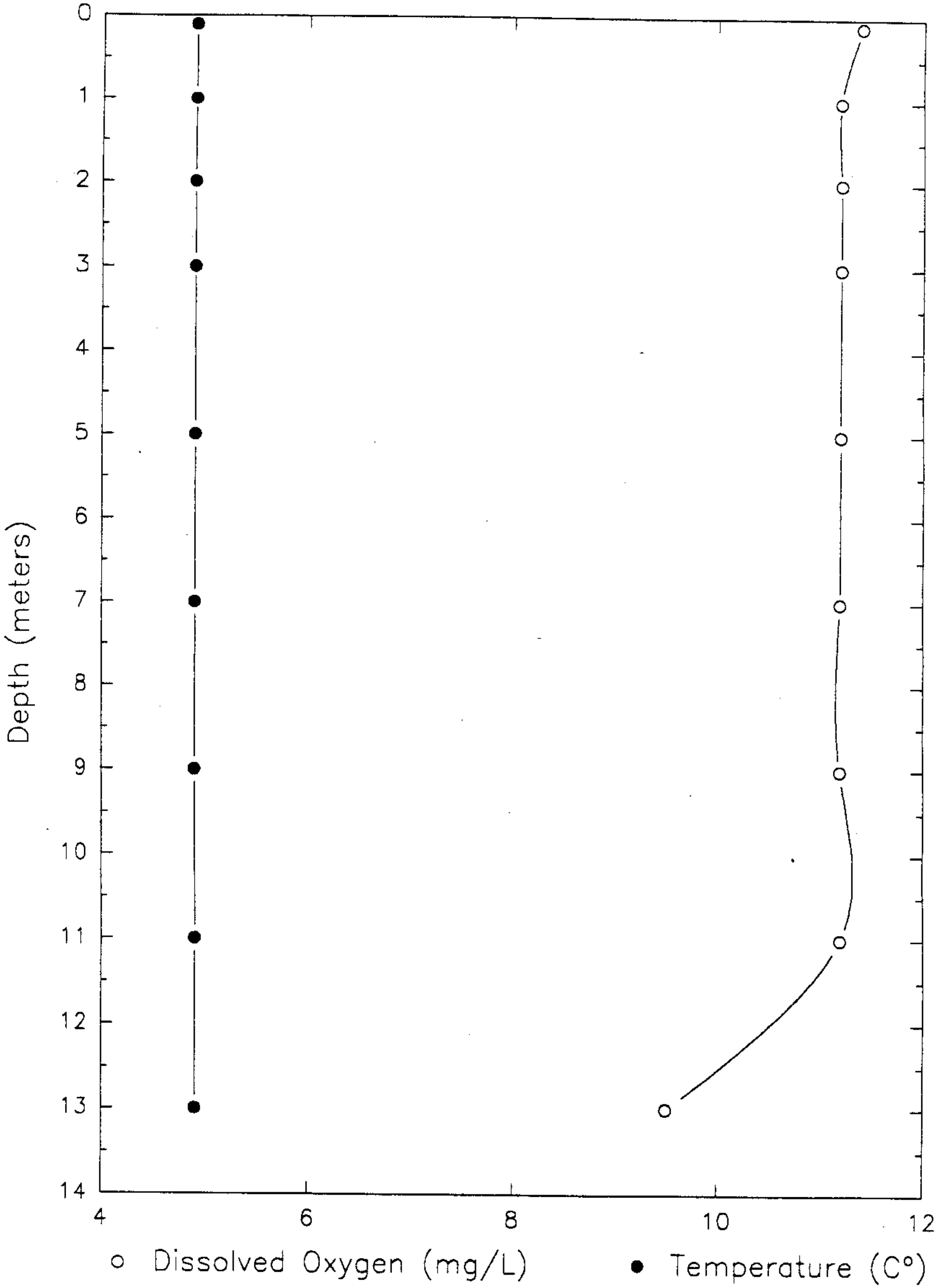
Beaver Lake

08/24/90



Beaver Lake

04/03/90



APPENDIX V-2

Beaver Lake Raw Dissolved Oxygen Temperature Data

Date	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
11/07/89	0.1	9.5	9.3	80.0	1039	13.7	clear and cool
	1.0	9.1	9.2	79.0	1039		
	2.0	9.0	9.2	79.0	1039		
	3.0	9.0	9.1	79.0	1039		
	4.0	9.0	9.1	79.0	1039		
	5.0	9.0	9.1	79.0	1039		
	6.0	8.9	9.2	77.0	1039		
	7.0	8.6	9.2	77.0	1039		
	8.0	8.5	9.3	78.0	1039		
	9.0	8.4	9.3	78.0	1039		
	10.0	8.3	9.2	77.0	1039		
	11.0	-99.0	-99.0	-99.0	1039		
	12.0	8.2	9.3	78.0	1039		
	13.0	8.2	9.3	78.0	1039		
03/13/90	12.0	4.0	5.5	41.0	1300	12.4	sunny, warm
04/03/90	0.1	4.9	11.4	86.0	1100	13.4	cold,cloudy
	1.0	4.9	11.2	85.0	1100		
	2.0	4.9	11.2	85.0	1100		
	3.0	4.9	11.2	85.0	1100		
	5.0	4.9	11.2	85.0	1100		
	7.0	4.9	11.2	85.0	1100		
	9.0	4.9	11.2	85.0	1100		
	11.0	4.9	11.2	85.0	1100		
	13.0	4.9	9.5	72.0	1100		
	13.0	4.9	9.5	72.0	1100		
05/10/90	0.1	11.6	11.6	114.0	1223	13.9	windy, warm, o'cast
	1.0	15.5	11.4	112.0	1224		
	2.0	15.2	11.3	111.0	1223		
	3.0	14.3	11.6	111.0	1223		
	4.0	13.8	11.4	107.0	1224		
	5.0	12.2	10.8	98.0	1224		windy, warm,o'cast
	6.0	10.0	10.4	91.0	1224		
	7.0	9.3	9.9	84.0	1224		
	8.0	8.8	9.3	78.0	1224		
	9.0	8.4	8.9	74.0	1224		
	10.0	8.3	8.7	72.0	1224		
	11.0	8.2	8.3	70.0	1224		
	12.0	8.0	7.6	63.0	1224		
	13.0	8.0	7.2	61.0	1224		
	13.5	8.0	7.3	61.0	1224		
06/13/90	0.1	20.7	9.8	106.0	1200	13.4	sunny and hot
	1.0	19.7	9.9	105.0	1200		

Beaver Lake Raw Dissolved Oxygen Temperature Data

Date	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	2.0	19.2	10.0	108.0	1200		
	3.0	18.0	9.6	100.0	1200		
	4.0	16.0	8.9	89.0	1200		
	5.0	12.2	7.4	68.0	1200		
	6.0	10.7	5.2	46.0	1200		
	7.0	9.7	3.8	33.0	1200		
	8.0	8.7	2.6	21.0	1200		
	9.0	8.2	2.7	23.0	1200		
	10.0	7.8	2.1	17.0	1200		
	11.0	7.5	1.7	14.0	1200		
	12.0	7.4	1.0	8.0	1200		
	13.0	7.3	0.3	2.0	1200		
07/13/90	0.1	23.2	9.0	103.5	1345	13.6	warm, breezy,partly cloudy
	1.0	22.5	8.9	102.8	1345		
	2.0	22.3	8.6	98.1	1345		
	3.0	22.1	8.5	97.4	1345		
	4.0	21.6	8.6	96.0	1345		
	5.0	15.8	6.1	55.0	1345		warm, breezy,partly clouy
	6.0	11.7	2.3	21.2	1345		
	7.0	9.8	-0.1	0.0	1345		
	8.0	9.1	-0.5	0.0	1345		
	9.0	8.5	-0.5	0.0	1345		
	10.0	8.0	-0.5	0.0	1345		
	11.0	7.7	-0.5	0.0	1345		
	12.0	7.5	-0.5	0.0	1345		
	13.0	7.4	-0.5	0.0	1345		
07/27/90	0.1	25.2	7.8	-99.0	1140	13.7	cloudy, calm
	1.0	25.2	7.7	-99.0	1140		
	2.0	25.2	7.5	-99.0	1140		
	3.0	25.1	7.4	-99.0	1140		
	4.0	22.6	6.6	-99.0	1140		
	5.0	17.1	4.0	-99.0	1140		
	6.0	12.7	1.5	-99.0	1140		
	7.0	10.2	0.7	-99.0	1140		
	8.0	9.5	0.7	-99.0	1140		
	9.0	8.8	0.7	-99.0	1140		
	10.0	8.2	0.7	-99.0	1140		
	11.0	7.9	0.7	-99.0	1140		
	12.0	7.8	0.7	-99.0	1140		
	13.0	7.8	0.7	-99.0	1140		
	13.5	7.8	0.8	-99.0	1140		
08/10/90	0.1	26.0	8.5	-99.0	1255		overcast

Beaver Lake Raw Dissolved Oxygen Temperature Data

Date	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	1.0	25.5	8.4	-99.0	1255		
	2.0	25.0	8.1	-99.0	1255		
	3.0	25.0	7.6	-99.0	1255		
	4.0	24.0	6.6	-99.0	1255		
	5.0	19.0	3.1	-99.0	1255		
	6.0	15.0	1.6	-99.0	1255		
	7.0	11.0	0.2	-99.0	1255		
	8.0	9.7	0.2	-99.0	1255		
	9.0	9.0	0.2	-99.0	1255		
	10.0	8.3	0.2	-99.0	1255		
	11.0	8.0	0.2	-99.0	1255		
	12.0	8.0	0.3	-99.0	1255		
	13.0	8.0	0.3	-99.0	1255		
	13.5	8.0	0.3	-99.0	1255		
08/24/90	0.1	22.8	8.4	-99.0	1225		
	1.0	22.6	8.3	-99.0	1225		
	2.0	22.5	8.3	-99.0	1225		
	3.0	22.4	8.2	-99.0	1225		
	4.0	22.2	7.7	-99.0	1225		
	5.0	20.8	4.9	-99.0	1225		
	6.0	14.8	1.8	-99.0	1225		
	7.0	11.2	0.6	-99.0	1225		
	8.0	9.8	0.6	-99.0	1225		
	9.0	8.6	0.6	-99.0	1225		
	10.0	8.2	0.5	-99.0	1225		
	11.0	8.0	0.5	-99.0	1225		
	12.0	7.8	0.5	-99.0	1225		
	13.0	7.6	0.7	-99.0	1225		
	13.5	7.6	0.7	-99.0	1225		
09/07/90	0.1	22.8	9.0	103.2	1225		cloudy,calm
	1.0	22.8	8.8	102.8	1225		
	2.0	22.7	8.8	102.0	1225		
	3.0	22.2	8.5	96.1	1225		
	4.0	21.4	7.3	82.6	1225		
	5.0	20.0	4.9	50.0	1225		
	6.0	15.6	3.9	38.9	1225		
	7.0	11.7	-0.5	0.0	1225		
	8.0	9.8	-0.5	0.0	1225		
	9.0	8.8	-0.5	0.0	1225		
	10.0	8.1	-0.5	0.0	1225		
	11.0	7.8	-0.5	0.0	1225		
	12.0	7.6	-0.5	0.0	1225		

Beaver Lake Raw Dissolved Oxygen Temperature Data

Date	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	13.0	7.5	-0.5	0.0	1225		
	13.5	7.5	-0.5	0.0	1225		
09/21/90	0.1	18.0	8.5	-99.0	1130	13.5	sunny,calm
	1.0	17.9	8.5	-99.0	1130		
	2.0	17.7	8.5	-99.0	1130		
	3.0	17.7	8.4	-99.0	1130		
	4.0	17.6	8.4	-99.0	1130		
	5.0	17.6	8.3	-99.0	1130		
	6.0	17.3	8.2	-99.0	1130		
	7.0	13.9	1.0	-99.0	1130		
	8.0	10.3	0.6	-99.0	1130		
	9.0	9.1	0.6	-99.0	1130		
	10.0	8.2	0.7	-99.0	1130		
	11.0	8.0	0.7	-99.0	1130		
	12.0	7.9	0.8	-99.0	1130		
	13.0	7.9	0.8	-99.0	1130		
10/05/90	0.1	16.2	8.6	-99.0	1045	13.7	sunny,windy
	1.0	16.2	8.7	-99.0	1045		
	2.0	16.2	8.7	-99.0	1045		
	3.0	16.2	8.7	-99.0	1045		
	4.0	16.0	8.6	-99.0	1045		
	5.0	16.0	8.5	-99.0	1045		
	6.0	16.0	8.2	-99.0	1045		
	7.0	15.5	7.8	-99.0	1045		
	8.0	13.0	0.7	-99.0	1045		
	9.0	9.5	0.7	-99.0	1045		
	10.0	8.5	0.7	-99.0	1045		
	11.0	8.0	0.3	-99.0	1045		
	12.0	8.0	0.6	-99.0	1045		
	13.0	8.0	0.3	-99.0	1045		
	13.5	7.8	0.3	-99.0	1045		
01/25/91	12.0	0.0	10.9	-99.0	1300	13.1	cold,windy

APPENDIX V-3

Beaver Lake Raw Chemistry Data

Date	* Station	pH	Alk	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Fecal
11/22/89	1	6.66	-99.00	153.50	0.011	-99.000	0.17	34	28	-99.0	-99.00	-10
12/06/89	1	-99.00	-99.00	162.00	0.011	-99.000	0.25	-99	29	-99.0	0.80	-10
12/19/89	1	-99.00	-99.00	-99.00	0.009	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/03/90	1	7.15	20.90	169.36	0.009	0.430	0.35	29	29	10.3	0.60	20
02/08/90	1	-99.00	-99.00	161.17	0.014	-99.000	0.47	-99	31	9.1	0.69	3
02/22/90	1	-99.00	-99.00	-99.00	0.016	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
03/08/90	1	6.64	-99.00	148.70	0.014	-99.000	-99.00	-99	29	-99.0	-99.00	2
03/20/90	1	-99.00	-99.00	-99.00	0.003	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/02/90	1	-99.00	-99.00	-99.00	0.015	-99.000	-99.00	-99	-99	-99.0	-99.00	-10
04/13/90	1	-99.00	-99.00	-99.00	0.017	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/19/90	1	-99.00	-99.00	145.80	0.012	0.330	0.36	23	28	-99.0	0.57	-10
05/01/90	1	-99.00	-99.00	147.50	0.014	-99.000	-99.00	20	28	-99.0	0.58	10
05/17/90	1	-99.00	-99.00	-99.00	0.007	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/05/90	1	-99.00	-99.00	147.54	0.008	-99.000	-99.00	24	27	-99.0	0.56	-10
06/20/90	1	-99.00	-99.00	-99.00	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
07/06/90	1	7.44	-99.00	154.30	0.012	0.390	-99.00	19	27	-99.0	0.48	20
07/20/90	1	-99.00	-99.00	-99.00	0.012	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
08/03/90	1	7.63	-99.00	154.60	0.014	-99.000	-99.00	22	-99	-99.0	0.70	-99
08/17/90	1	-99.00	-99.00	156.00	0.007	-99.000	-99.00	-99	28	-99.0	-99.00	-10
09/28/90	1	7.51	-99.00	153.09	0.007	-99.000	-99.00	-99	28	-99.0	0.40	-99
10/16/90	1	6.79	22.20	155.70	0.018	0.270	-0.05	37	27	-99.0	1.00	120
10/26/90	1	-99.00	-99.00	-99.00	0.018	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/02/90	1	-99.00	-99.00	-99.00	0.016	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/13/90	1	-99.00	-99.00	146.30	0.023	-99.000	-99.00	-99	25	-99.0	1.80	86
12/06/90	1	-99.00	-99.00	144.60	0.021	-99.000	-99.00	-99	24	-99.0	-99.00	-99
12/28/90	1	-99.00	-99.00	-99.00	0.017	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/04/91	1	7.07	15.70	143.70	0.015	0.250	0.38	32	24	-99.0	0.50	-99
01/31/91	1	-99.00	-99.00	-99.00	0.002	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	1	7.21	-99.00	-99.00	0.007	-99.000	-99.00	-99	-99	-99.0	0.49	0
06/12/91	1	-99.00	-99.00	-99.00	0.009	-99.000	-99.00	-99	-99	-99.0	-99.00	20
11/22/89	2	6.66	-99.00	153.30	0.010	-99.000	0.17	34	28	-99.0	-99.00	-10
12/06/89	2	-99.00	-99.00	164.70	0.011	-99.000	0.25	-99	29	-99.0	0.80	-10
12/19/89	2	-99.00	-99.00	-99.00	0.014	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/03/90	2	-99.00	-99.00	178.50	0.007	0.430	0.39	28	31	10.0	0.50	-10
02/08/90	2	-99.00	-99.00	170.77	0.015	-99.000	0.49	-99	35	9.4	0.79	18
02/22/90	2	-99.00	-99.00	-99.00	0.014	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
03/08/90	2	6.60	-99.00	162.70	0.013	-99.000	-99.00	-99	28	-99.0	-99.00	1
03/20/90	2	-99.00	-99.00	-99.00	0.006	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/02/90	2	-99.00	-99.00	-99.00	0.019	-99.000	-99.00	-99	-99	-99.0	-99.00	-10
04/13/90	2	-99.00	-99.00	-99.00	0.015	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/19/90	2	6.88	14.70	146.90	0.011	0.140	0.36	24	28	-99.0	0.64	-10
05/01/90	2	-99.00	-99.00	146.90	0.011	-99.000	-99.00	19	28	-99.0	0.74	10
05/17/90	2	-99.00	-99.00	-99.00	0.010	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/20/90	2	-99.00	-99.00	-99.00	0.014	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
07/06/90	2	7.36	17.00	150.50	0.012	0.340	-99.00	23	27	-99.0	0.68	10

*see Table IV-2

Beaver Lake Raw Chemistry Data

Date	Station	pH	Alk	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Fecal
08/17/90	2	-99.00	-99.00	155.50	0.006	-99.000	-99.00	-99	28	-99.0	-99.00	10
09/13/90	2	-99.00	-99.00	-99.00	0.008	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
09/28/90	2	7.37	-99.00	152.24	0.007	-99.000	-99.00	-99	27	-99.0	0.50	-99
10/26/90	2	-99.00	-99.00	-99.00	0.019	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/02/90	2	-99.00	-99.00	-99.00	0.018	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/13/90	2	-99.00	-99.00	146.20	0.024	-99.000	-99.00	-99	25	-99.0	1.70	106
12/06/90	2	-99.00	-99.00	145.50	0.021	-99.000	-99.00	-99	24	-99.0	-99.00	-99
12/28/90	2	-99.00	-99.00	-99.00	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/04/91	2	-99.00	-99.00	142.60	0.017	0.400	0.36	30	24	-99.0	0.52	-99
01/31/91	2	-99.00	-99.00	-99.00	0.002	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	2	7.22	-99.00	-99.00	0.009	-99.000	-99.00	-99	-99	-99.0	0.42	0
06/12/91	2	-99.00	-99.00	-99.00	0.008	-99.000	-99.00	-99	-99	-99.0	-99.00	10
11/22/89	3	6.53	-99.00	61.00	0.012	-99.000	0.16	8	5	-99.0	-99.00	-10
12/06/89	3	-99.00	-99.00	64.00	0.011	-99.000	0.35	-99	5	-99.0	0.35	-10
12/19/89	3	-99.00	-99.00	-99.00	0.040	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/03/90	3	6.61	11.60	80.08	0.131	0.660	0.55	20	8	9.2	12.80	-10
02/08/90	3	-99.00	-99.00	127.30	0.039	-99.000	0.32	-99	25	9.0	3.80	0
02/22/90	3	-99.00	-99.00	-99.00	0.340	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
03/08/90	3	6.34	-99.00	62.23	0.030	-99.000	-99.00	-99	6	-99.0	-99.00	0
03/20/90	3	-99.00	-99.00	-99.00	0.016	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/02/90	3	-99.00	-99.00	-99.00	0.017	-99.000	-99.00	-99	-99	-99.0	-99.00	-10
04/13/90	3	-99.00	-99.00	-99.00	0.024	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/19/90	3	6.60	5.40	96.90	0.011	0.110	0.23	5	16	-99.0	0.55	-10
05/01/90	3	-99.00	-99.00	63.90	0.012	-99.000	-99.00	7	8	-99.0	1.02	-10
05/17/90	3	-99.00	-99.00	-99.00	0.016	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/05/90	3	-99.00	-99.00	53.35	0.007	-99.000	-99.00	8	6	-99.0	0.34	-10
06/20/90	3	-99.00	-99.00	-99.00	0.016	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
09/13/90	3	-99.00	-99.00	-99.00	0.008	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
10/16/90	3	6.75	5.50	66.40	0.013	-0.100	0.11	27	5	-99.0	0.40	30
10/26/90	3	-99.00	-99.00	-99.00	0.006	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/02/90	3	-99.00	-99.00	-99.00	0.006	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/13/90	3	-99.00	-99.00	67.60	0.015	-99.000	-99.00	-99	8	-99.0	0.70	7
12/06/90	3	-99.00	-99.00	55.40	0.010	-99.000	-99.00	-99	5	-99.0	-99.00	-99
12/28/90	3	-99.00	-99.00	-99.00	0.005	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/04/91	3	5.92	0.60	66.30	0.012	0.700	0.25	6	7	-99.0	0.40	-99
01/18/91	3	-99.00	-99.00	-99.00	0.002	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/31/91	3	-99.00	-99.00	-99.00	0.039	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	3	6.18	-99.00	-99.00	0.005	-99.000	-99.00	-99	-99	-99.0	0.30	2
11/22/89	4	7.09	-99.00	243.60	0.007	-99.000	0.68	17	47	-99.0	-99.00	10
12/06/89	4	-99.00	-99.00	276.00	0.019	-99.000	1.08	-99	54	-99.0	1.04	40
12/19/89	4	-99.00	-99.00	-99.00	0.014	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/03/90	4	7.00	23.00	301.67	0.015	0.290	1.17	14	62	12.2	2.00	-10
02/08/90	4	-99.00	-99.00	253.00	0.015	-99.000	0.98	-99	53	11.7	0.85	0
02/22/90	4	-99.00	-99.00	-99.00	0.018	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
03/08/90	4	7.20	-99.00	261.00	0.015	-99.000	-99.00	-99	51	-99.0	-99.00	0

Beaver Lake Raw Chemistry Data

Date	Station	pH	Alk	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Fecal
03/20/90	4	-99.00	-99.00	-99.00	0.033	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/02/90	4	-99.00	-99.00	-99.00	0.017	-99.000	-99.00	-99	-99	-99.0	-99.00	10
04/13/90	4	-99.00	-99.00	-99.00	0.009	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/19/90	4	7.33	17.10	226.20	0.015	0.540	0.89	14	44	-99.0	0.91	-10
05/01/90	4	-99.00	-99.00	233.20	0.012	-99.000	-99.00	25	46	-99.0	0.30	30
05/17/90	4	-99.00	-99.00	-99.00	0.011	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/05/90	4	-99.00	-99.00	271.00	0.008	-99.000	-99.00	12	57	-99.0	0.17	-10
06/20/90	4	-99.00	-99.00	-99.00	0.010	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
07/06/90	4	7.44	27.00	250.00	0.012	0.220	-99.00	7	49	-99.0	0.30	-10
09/13/90	4	-99.00	-99.00	-99.00	0.061	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
10/16/90	4	7.05	24.80	265.00	0.016	0.290	0.39	44	50	-99.0	0.50	100
10/26/90	4	-99.00	-99.00	-99.00	0.011	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/02/90	4	-99.00	-99.00	-99.00	0.007	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/13/90	4	-99.00	-99.00	203.80	0.014	-99.000	-99.00	-99	36	-99.0	1.10	113
12/06/90	4	-99.00	-99.00	198.00	0.009	-99.000	-99.00	-99	36	-99.0	-99.00	-99
12/28/90	4	-99.00	-99.00	-99.00	0.022	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/04/91	4	6.98	21.00	218.20	0.012	0.230	1.05	15	37	-99.0	0.65	-99
01/18/91	4	-99.00	-99.00	-99.00	0.023	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/31/91	4	-99.00	-99.00	-99.00	0.051	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	4	7.23	-99.00	-99.00	0.010	-99.000	-99.00	-99	-99	-99.0	0.35	3
06/12/91	4	-99.00	-99.00	-99.00	0.010	-99.000	-99.00	-99	-99	-99.0	-99.00	190
11/22/89	5	7.25	-99.00	231.10	-0.001	-99.000	0.31	44	47	-99.0	-99.00	-10
12/06/89	5	-99.00	-99.00	289.00	0.015	-99.000	0.54	-99	58	-99.0	0.63	10
12/19/89	5	-99.00	-99.00	-99.00	0.014	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/03/90	5	6.98	28.40	376.36	0.030	0.820	0.54	32	81	14.4	1.40	200
02/08/90	5	-99.00	-99.00	303.00	0.017	-99.000	0.71	-99	68	11.2	0.49	3
03/08/90	5	7.17	-99.00	280.33	0.021	-99.000	-99.00	-99	60	-99.0	-99.00	0
03/20/90	5	-99.00	-99.00	-99.00	0.034	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/02/90	5	-99.00	-99.00	-99.00	0.026	-99.000	-99.00	-99	-99	-99.0	-99.00	-10
04/13/90	5	-99.00	-99.00	-99.00	0.017	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/19/90	5	7.11	16.50	237.60	0.020	0.330	0.34	26	50	-99.0	0.50	-10
05/01/90	5	-99.00	-99.00	232.70	0.023	-99.000	-99.00	36	50	-99.0	0.86	10
05/17/90	5	-99.00	-99.00	-99.00	0.031	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/05/90	5	-99.00	-99.00	300.00	0.027	-99.000	-99.00	36	66	-99.0	0.62	30
06/20/90	5	-99.00	-99.00	-99.00	0.031	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
07/06/90	5	6.96	30.00	330.00	0.021	0.650	-99.00	30	73	-99.0	2.00	170
08/17/90	5	-99.00	-99.00	310.00	0.013	-99.000	-99.00	-99	63	-99.0	-99.00	150
09/13/90	5	-99.00	-99.00	-99.00	0.016	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
09/28/90	5	7.17	-99.00	352.00	0.004	-99.000	-99.00	-99	57	-99.0	10.10	-99
10/16/90	5	7.33	17.30	215.00	0.029	0.450	-0.05	96	42	-99.0	1.20	90
10/26/90	5	-99.00	-99.00	-99.00	0.044	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/02/90	5	-99.00	-99.00	-99.00	0.014	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/13/90	5	-99.00	-99.00	206.80	0.049	-99.000	-99.00	-99	39	-99.0	4.90	39
12/06/90	5	-99.00	-99.00	209.00	0.015	-99.000	-99.00	-99	40	-99.0	-99.00	-99
12/28/90	5	-99.00	-99.00	-99.00	0.016	-99.000	-99.00	-99	-99	-99.0	-99.00	-99

Beaver Lake Raw Chemistry Data

Date	Station	pH	Alk	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Fecal
01/04/91	5	7.22	19.40	239.50	0.015	0.600	0.61	26	45	-99.0	0.46	-99
01/18/91	5	-99.00	-99.00	-99.00	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/31/91	5	-99.00	-99.00	-99.00	0.027	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	5	7.34	-99.00	-99.00	0.011	-99.000	-99.00	-99	-99	-99.0	0.26	2
06/12/91	5	-99.00	-99.00	-99.00	0.031	-99.000	-99.00	-99	-99	-99.0	-99.00	590
11/22/89	6	7.09	-99.00	115.10	0.010	-99.000	0.45	52	18	-99.0	-99.00	-10
12/06/89	6	-99.00	-99.00	133.70	0.010	-99.000	0.60	-99	20	-99.0	0.73	30
12/19/89	6	-99.00	-99.00	-99.00	0.009	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/03/90	6	6.86	20.10	167.61	0.015	0.540	0.52	33	27	9.9	1.10	10
02/08/90	6	-99.00	-99.00	131.87	0.010	-99.000	0.50	-99	23	8.4	0.60	0
02/22/90	6	-99.00	-99.00	-99.00	0.012	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
03/08/90	6	6.60	-99.00	118.30	0.009	-99.000	-99.00	-99	20	-99.0	-99.00	0
03/20/90	6	-99.00	-99.00	-99.00	0.008	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/02/90	6	-99.00	-99.00	-99.00	0.012	-99.000	-99.00	-99	-99	-99.0	-99.00	20
04/13/90	6	-99.00	-99.00	-99.00	0.012	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/19/90	6	6.84	11.10	112.20	0.011	0.160	0.21	14	19	-99.0	0.47	-10
05/01/90	6	-99.00	-99.00	125.20	0.018	-99.000	-99.00	34	21	-99.0	0.86	70
05/17/90	6	-99.00	-99.00	-99.00	0.018	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/05/90	6	-99.00	-99.00	112.90	0.016	-99.000	-99.00	44	18	-99.0	0.81	60
06/20/90	6	-99.00	-99.00	-99.00	0.031	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
07/06/90	6	6.82	18.40	115.10	0.021	0.420	-99.00	48	18	-99.0	0.95	120
07/20/90	6	-99.00	-99.00	-99.00	0.042	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
08/03/90	6	6.62	-99.00	138.40	0.034	-99.000	-99.00	130	-99	-99.0	2.30	-99
08/17/90	6	-99.00	-99.00	130.80	0.022	-99.000	-99.00	-99	20	-99.0	-99.00	30
09/13/90	6	-99.00	-99.00	-99.00	0.021	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
09/28/90	6	6.64	-99.00	133.48	0.013	-99.000	-99.00	-99	21	-99.0	1.10	-99
10/16/90	6	6.54	13.30	113.70	0.024	0.350	0.06	106	18	-99.0	1.30	110
10/26/90	6	-99.00	-99.00	-99.00	0.017	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/02/90	6	-99.00	-99.00	-99.00	0.018	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/13/90	6	-99.00	-99.00	92.80	0.016	-99.000	-99.00	-99	13	-99.0	1.70	173
12/06/90	6	-99.00	-99.00	107.10	0.010	-99.000	-99.00	-99	15	-99.0	-99.00	-99
12/28/90	6	-99.00	-99.00	-99.00	0.010	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/04/91	6	6.72	11.60	109.20	0.013	0.170	0.51	31	15	-99.0	0.73	-99
01/18/91	6	-99.00	-99.00	-99.00	0.005	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/31/91	6	-99.00	-99.00	-99.00	0.065	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	6	7.10	-99.00	-99.00	0.010	-99.000	-99.00	-99	-99	-99.0	0.43	0
06/12/91	6	-99.00	-99.00	-99.00	0.020	-99.000	-99.00	-99	-99	-99.0	-99.00	120
11/22/89	7	6.80	-99.00	80.90	0.015	-99.000	-0.05	130	6	-99.0	-99.00	-10
12/06/89	7	-99.00	-99.00	128.00	0.016	-99.000	-0.05	-99	11	-99.0	1.12	-10
12/19/89	7	-99.00	-99.00	-99.00	0.010	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/03/90	7	6.35	37.90	169.56	0.016	0.270	0.16	27	17	15.2	1.00	-10
02/08/90	7	-99.00	-99.00	244.00	0.141	-99.000	0.07	-99	49	10.0	17.10	0
02/22/90	7	-99.00	-99.00	-99.00	1.410	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
03/08/90	7	5.92	-99.00	97.58	0.035	-99.000	-99.00	-99	9	-99.0	-99.00	0
03/20/90	7	-99.00	-99.00	-99.00	0.033	-99.000	-99.00	-99	-99	-99.0	-99.00	-99

Beaver Lake Raw Chemistry Data

Date	Station	pH	Alk	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Fecal
04/13/90	7	-99.00	-99.00	-99.00	0.169	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/19/90	7	6.80	14.20	68.90	0.029	0.440	-0.05	94	5	-99.0	5.00	-10
05/01/90	7	-99.00	-99.00	108.10	0.038	-99.000	-99.00	110	14	-99.0	5.20	130
05/17/90	7	-99.00	-99.00	-99.00	0.055	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/05/90	7	-99.00	-99.00	112.80	0.032	-99.000	-99.00	110	11	-99.0	3.20	20
06/20/90	7	-99.00	-99.00	-99.00	0.053	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
07/06/90	7	7.52	46.20	174.80	0.034	0.480	-99.00	50	17	-99.0	5.50	40
09/13/90	7	-99.00	-99.00	-99.00	0.039	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
09/28/90	7	-99.00	-99.00	246.00	-99.000	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
10/16/90	7	-99.00	-99.00	85.90	0.332	0.850	-0.05	-99	5	-99.0	92.00	690
10/26/90	7	-99.00	-99.00	-99.00	0.110	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/02/90	7	-99.00	-99.00	-99.00	0.050	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/13/90	7	-99.00	-99.00	75.80	0.096	-99.000	-99.00	-99	5	-99.0	20.00	25
12/06/90	7	-99.00	-99.00	75.70	0.011	-99.000	-99.00	-99	6	-99.0	-99.00	-99
12/28/90	7	-99.00	-99.00	-99.00	0.036	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/04/91	7	6.43	21.60	99.90	0.026	0.400	-0.05	85	8	-99.0	2.70	-99
01/18/91	7	-99.00	-99.00	-99.00	0.021	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/31/91	7	-99.00	-99.00	-99.00	0.033	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	7	6.74	-99.00	-99.00	0.018	-99.000	-99.00	-99	-99	-99.0	1.02	0
06/12/91	7	-99.00	-99.00	-99.00	0.046	-99.000	-99.00	-99	-99	-99.0	-99.00	530
11/22/89	8	7.19	-99.00	542.70	0.004	-99.000	1.28	17	71	-99.0	-99.00	20
12/06/89	8	-99.00	-99.00	615.00	0.070	-99.000	1.50	-99	144	-99.0	0.64	30
12/19/89	8	-99.00	-99.00	-99.00	0.025	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/03/90	8	7.18	55.60	723.06	0.022	0.430	1.97	-10	163	20.3	1.70	20
02/08/90	8	-99.00	-99.00	609.00	0.012	-99.000	1.80	-99	138	18.0	0.62	36
02/22/90	8	-99.00	-99.00	-99.00	0.012	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
03/08/90	8	7.24	-99.00	222.36	0.019	-99.000	-99.00	-99	122	-99.0	-99.00	4
03/20/90	8	-99.00	-99.00	-99.00	0.020	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/02/90	8	-99.00	-99.00	-99.00	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-10
04/13/90	8	-99.00	-99.00	-99.00	0.010	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/19/90	8	7.58	36.70	520.00	0.021	0.300	1.50	9	119	-99.0	0.40	10
05/01/90	8	-99.00	-99.00	511.60	0.066	-99.000	-99.00	-99	114	-99.0	0.47	10
05/17/90	8	-99.00	-99.00	-99.00	0.007	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/05/90	8	-99.00	-99.00	566.00	0.008	-99.000	-99.00	12	122	-99.0	0.33	10
06/20/90	8	-99.00	-99.00	-99.00	0.010	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
07/06/90	8	7.68	6.34	590.00	0.022	0.370	-99.00	25	129	-99.0	1.44	40
08/03/90	8	7.12	-99.00	260.00	-99.000	-99.000	-99.00	84	-99	-99.0	7.00	-99
08/17/90	8	-99.00	-99.00	617.70	-99.000	-99.000	-99.00	-99	131	-99.0	-99.00	-99
09/13/90	8	-99.00	-99.00	-99.00	0.037	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
09/28/90	8	7.33	-99.00	617.00	0.003	-99.000	-99.00	-99	131	-99.0	0.70	-99
10/16/90	8	7.42	57.00	591.00	0.008	0.340	0.44	32	127	-99.0	0.80	100
10/26/90	8	-99.00	-99.00	-99.00	0.007	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/02/90	8	-99.00	-99.00	-99.00	0.084	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/13/90	8	-99.00	-99.00	437.30	0.007	-99.000	-99.00	-99	88	-99.0	0.50	104
12/06/90	8	-99.00	-99.00	483.00	0.007	-99.000	-99.00	-99	95	-99.0	-99.00	-99

Beaver Lake Raw Chemistry Data

Date	Station	pH	Alk	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Fecal
12/28/90	8	-99.00	-99.00	-99.00	0.011	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/04/91	8	7.27	43.50	489.20	0.012	0.430	0.86	7	28	-99.0	0.43	-99
01/31/91	8	-99.00	-99.00	-99.00	0.024	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	8	7.47	-99.00	-99.00	0.016	-99.000	-99.00	-99	-99	-99.0	0.30	3
06/12/91	8	-99.00	-99.00	-99.00	0.014	-99.000	-99.00	-99	-99	-99.0	-99.00	99
11/22/89	9	7.09	-99.00	209.90	0.007	-99.000	0.60	19	35	-99.0	-99.00	-10
12/06/89	9	-99.00	-99.00	248.60	0.009	-99.000	0.67	-99	41	-99.0	0.82	-10
12/19/89	9	-99.00	-99.00	-99.00	0.056	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/03/90	9	6.55	28.00	339.12	0.021	0.680	0.65	21	70	14.4	1.00	-10
02/08/90	9	-99.00	-99.00	257.00	0.013	-99.000	0.69	-99	49	12.7	1.36	20
02/22/90	9	-99.00	-99.00	-99.00	0.012	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
03/08/90	9	6.74	-99.00	556.00	0.005	-99.000	-99.00	-99	39	-99.0	-99.00	2
03/20/90	9	-99.00	-99.00	-99.00	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/02/90	9	-99.00	-99.00	-99.00	0.015	-99.000	-99.00	-99	-99	-99.0	-99.00	30
04/13/90	9	-99.00	-99.00	-99.00	0.012	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/19/90	9	7.06	22.60	186.00	0.012	0.110	0.34	12	32	-99.0	0.44	10
05/01/90	9	-99.00	-99.00	183.30	0.016	-99.000	-99.00	-23	32	-99.0	0.59	370
05/17/90	9	-99.00	-99.00	-99.00	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/05/90	9	-99.00	-99.00	198.00	0.024	-99.000	-99.00	39	32	-99.0	1.14	340
06/20/90	9	-99.00	-99.00	-99.00	0.048	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
07/06/90	9	-99.00	-99.00	230.00	0.040	0.540	-99.00	70	41	-99.0	2.80	30
07/20/90	9	-99.00	-99.00	-99.00	0.068	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
08/03/90	9	7.19	-99.00	513.00	0.019	-99.000	-99.00	136	-99	-99.0	5.50	-99
08/17/90	9	-99.00	-99.00	230.10	0.044	-99.000	-99.00	-99	38	-99.0	-99.00	20
09/13/90	9	-99.00	-99.00	-99.00	0.037	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
09/28/90	9	7.19	-99.00	-99.00	0.024	-99.000	-99.00	-99	41	-99.0	2.60	-99
10/16/90	9	6.78	28.90	196.50	0.025	0.380	0.06	70	32	-99.0	1.60	250
10/26/90	9	-99.00	-99.00	-99.00	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/02/90	9	-99.00	-99.00	-99.00	0.009	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/13/90	9	-99.00	-99.00	170.90	0.011	-99.000	-99.00	-99	24	-99.0	1.50	85
12/06/90	9	-99.00	-99.00	166.90	0.010	-99.000	-99.00	-99	25	-99.0	-99.00	-99
12/28/90	9	-99.00	-99.00	-99.00	0.008	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/04/91	9	6.97	26.00	195.80	0.011	0.320	1.88	10	115	-99.0	0.57	-99
01/31/91	9	-99.00	-99.00	-99.00	0.030	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	9	7.02	-99.00	-99.00	0.007	-99.000	-99.00	-99	-99	-99.0	0.31	40
06/12/91	9	-99.00	-99.00	-99.00	0.050	-99.000	-99.00	-99	-99	-99.0	-99.00	340
04/13/90	10	-99.00	-99.00	-99.00	0.084	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/19/90	10	6.75	21.40	314.90	0.064	0.410	0.45	13	67	-99.0	2.10	30
05/01/90	10	-99.00	-99.00	316.10	0.085	-99.000	-99.00	-99	-99	-99.0	30.00	500
05/17/90	10	-99.00	-99.00	-99.00	0.105	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/05/90	10	-99.00	-99.00	208.00	0.056	-99.000	-99.00	17	36	-99.0	2.70	510
08/17/90	10	-99.00	-99.00	224.60	0.011	-99.000	-99.00	-99	34	-99.0	-99.00	20
09/13/90	10	-99.00	-99.00	-99.00	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
10/16/90	10	7.01	30.10	286.00	0.071	0.360	1.50	32	47	-99.0	1.30	80
11/02/90	10	-99.00	-99.00	-99.00	0.088	-99.000	-99.00	-99	-99	-99.0	-99.00	-99

Beaver Lake Raw Chemistry Data

Date	Station	pH	Alk	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Fecal
11/13/90	10	-99.00	-99.00	341.90	0.074	-99.000	-99.00	-99	55	-99.0	2.90	200
01/04/91	10	6.24	28.10	213.10	0.032	0.680	1.12	7	30	-99.0	2.60	-99
01/31/91	10	-99.00	-99.00	-99.00	0.012	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	10	6.52	-99.00	-99.00	0.021	-99.000	-99.00	-99	-99	-99.0	0.60	4
06/20/90	11	-99.00	-99.00	-99.00	0.021	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
07/06/90	11	7.67	52.80	380.00	0.028	2.000	-99.00	24	57	-99.0	0.68	80
07/20/90	11	-99.00	-99.00	-99.00	0.115	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
09/13/90	11	-99.00	-99.00	-99.00	0.029	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
09/28/90	11	7.81	-99.00	370.00	0.019	-99.000	-99.00	-99	46	-99.0	0.40	-99
10/16/90	11	6.90	34.20	300.00	0.017	0.270	0.17	69	41	-99.0	0.80	100
10/26/90	11	-99.00	-99.00	-99.00	0.012	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/02/90	11	-99.00	-99.00	-99.00	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
11/13/90	11	-99.00	-99.00	312.10	0.014	-99.000	-99.00	-99	46	-99.0	1.40	96
12/06/90	11	-99.00	-99.00	316.00	0.012	-99.000	-99.00	-99	46	-99.0	-99.00	-99
12/28/90	11	-99.00	-99.00	-99.00	0.011	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/04/91	11	7.00	35.10	384.10	0.029	0.380	1.51	7	58	-99.0	0.81	-99
01/31/91	11	-99.00	-99.00	-99.00	0.024	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	11	7.10	-99.00	-99.00	0.015	-99.000	-99.00	-99	-99	-99.0	0.31	200
06/12/91	11	-99.00	-99.00	-99.00	0.030	-99.000	-99.00	-99	-99	-99.0	-99.00	160
03/08/90	12	-99.00	-99.00	-99.00	-99.000	-99.000	-99.00	-99	-99	-99.0	-99.00	-30
04/02/90	12	-99.00	-99.00	-99.00	0.021	-99.000	-99.00	-99	-99	-99.0	-99.00	-10
04/19/90	12	-99.00	-99.00	-99.00	0.022	-99.000	-99.00	-99	-99	-99.0	-99.00	0
07/06/90	12	-99.00	-99.00	-99.00	0.084	0.850	-99.00	-99	-99	-99.0	-99.00	10
12/28/90	12	-99.00	-99.00	-99.00	0.014	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	12	7.02	-99.00	-99.00	0.015	-99.000	-99.00	-99	-99	-99.0	0.41	0
01/03/90	13	-99.00	-99.00	-99.00	0.021	-99.000	-99.00	29	-99	-99.0	-99.00	40
04/02/90	13	-99.00	-99.00	-99.00	0.026	-99.000	-99.00	-99	-99	-99.0	-99.00	330
04/19/90	13	-99.00	-99.00	-99.00	0.014	-99.000	-99.00	-99	-99	-99.0	-99.00	0
07/06/90	13	-99.00	-99.00	-99.00	0.028	0.340	-99.00	-99	-99	-99.0	-99.00	-10
08/17/90	13	-99.00	-99.00	346.30	0.026	-99.000	-99.00	-99	43	-99.0	-99.00	780
12/28/90	13	-99.00	-99.00	-99.00	0.010	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	13	6.68	-99.00	-99.00	0.012	-99.000	-99.00	-99	-99	-99.0	0.76	1
01/03/90	14	-99.00	-99.00	-99.00	0.015	-99.000	-99.00	39	-99	-99.0	-99.00	-10
04/02/90	14	-99.00	-99.00	-99.00	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-10
04/19/90	14	-99.00	-99.00	-99.00	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	0
07/06/90	14	-99.00	-99.00	-99.00	0.019	0.340	-99.00	-99	-99	-99.0	-99.00	170
12/28/90	14	-99.00	-99.00	-99.00	0.011	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
04/03/91	14	6.98	-99.00	-99.00	0.008	-99.000	-99.00	-99	-99	-99.0	0.44	1
05/10/90	20	7.18	-99.00	148.20	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/13/90	20	7.43	-99.00	148.00	0.009	-99.000	-99.00	25	-99	-99.0	-99.00	-99
06/28/90	20	7.34	14.60	149.60	0.013	0.340	0.07	27	27	7.0	-99.00	-99
07/13/90	20	7.55	17.00	151.40	0.011	-99.000	-99.00	26	-99	-99.0	-99.00	-99
07/27/90	20	7.52	17.10	153.70	0.010	0.210	-0.05	24	8	4.0	-99.00	-99
08/10/90	20	7.58	18.40	154.30	0.006	-99.000	-99.00	16	-99	-99.0	-99.00	-99
08/24/90	20	7.37	22.70	156.50	0.012	-99.000	-99.00	27	-99	-99.0	-99.00	-99

Beaver Lake Raw Chemistry Data

Date	Station	pH	Alk	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Fecal
09/07/90	20	7.44	-99.00	153.80	0.009	-99.000	-99.00	32	-99	-99.0	-99.00	-99
09/21/90	20	7.49	-99.00	152.99	0.010	0.280	-0.05	26	27	8.0	-99.00	-99
10/05/90	20	7.30	-99.00	155.30	0.008	0.330	-0.05	34	27	7.0	-99.00	-99
04/29/91	20	-99.00	-99.00	-99.00	0.001	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
05/22/91	20	7.51	16.50	141.50	0.018	0.410	0.07	29	24	8.0	-99.00	-99
06/05/91	20	7.39	17.70	144.30	0.004	-99.000	-0.05	22	23	8.0	-99.00	-99
07/05/91	20	7.51	14.30	146.60	0.010	-99.000	-0.05	17	25	7.0	-99.00	-99
08/08/91	20	7.36	20.90	143.50	0.012	-99.000	-0.05	11	25	8.0	-99.00	-99
05/10/90	21	7.09	-99.00	151.15	0.015	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/13/90	21	6.90	-99.00	144.60	0.090	-99.000	-99.00	28	-99	-99.0	-99.00	-99
06/28/90	21	6.69	15.60	145.50	0.019	0.290	-99.00	28	-99	-99.0	-99.00	-99
07/13/90	21	6.73	15.20	149.00	0.016	-99.000	-99.00	28	-99	-99.0	-99.00	-99
07/27/90	21	6.90	16.90	149.00	0.018	0.260	-99.00	33	-99	-99.0	-99.00	-99
08/10/90	21	6.86	-99.00	151.10	0.013	-99.000	-99.00	23	-99	-99.0	-99.00	-99
08/24/90	21	7.35	18.60	157.10	0.012	-99.000	-99.00	26	-99	-99.0	-99.00	-99
09/07/90	21	6.68	-99.00	151.20	0.028	-99.000	-99.00	44	-99	-99.0	-99.00	-99
09/21/90	21	6.95	-99.00	155.22	0.018	0.390	-0.05	32	27	7.0	-99.00	-99
10/05/90	21	6.98	-99.00	158.20	0.027	0.320	-0.05	37	27	6.0	-99.00	-99
04/29/91	21	7.16	4.50	142.60	0.016	0.330	0.29	29	25	9.0	-99.00	-99
05/22/91	21	7.41	16.00	142.01	0.019	-99.000	0.10	27	24	8.0	-99.00	-99
06/05/91	21	7.24	15.80	140.70	0.011	-99.000	0.08	23	22	8.0	-99.00	-99
07/05/91	21	6.66	15.70	146.20	0.018	-99.000	-99.00	21	-99	-99.0	-99.00	-99
08/08/91	21	6.89	21.60	305.50	0.047	-99.000	-99.00	34	-99	-99.0	-99.00	-99
05/10/90	22	6.67	-99.00	147.40	0.012	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
06/13/90	22	6.57	-99.00	148.10	0.013	-99.000	-99.00	25	-99	-99.0	-99.00	-99
06/28/90	22	6.50	-99.00	150.20	0.018	0.420	0.13	37	27	7.0	-99.00	-99
07/13/90	22	6.70	18.40	152.30	0.017	-99.000	-99.00	48	-99	-99.0	-99.00	-99
07/27/90	22	6.54	18.70	153.10	0.034	0.490	-99.00	57	-99	-99.0	-99.00	-99
08/10/90	22	6.77	-99.00	159.30	0.016	-99.000	-99.00	33	-99	-99.0	-99.00	-99
08/24/90	22	6.77	23.70	168.60	0.025	-99.000	-99.00	100	-99	-99.0	-99.00	-99
09/07/90	22	6.72	-99.00	166.10	0.024	-99.000	-99.00	64	-99	-99.0	-99.00	-99
09/21/90	22	6.83	-99.00	167.31	-99.000	0.028	-0.05	110	27	4.0	-99.00	-99
10/05/90	22	6.88	-99.00	178.90	0.037	0.940	-0.05	110	27	2.0	-99.00	-99
04/29/91	22	7.06	9.00	145.60	0.006	0.320	0.31	32	25	9.0	-99.00	-99
05/22/91	22	6.61	-99.00	147.70	0.015	0.270	0.22	23	25	8.0	-99.00	-99
06/05/91	22	6.70	16.80	145.80	0.010	-99.000	0.12	28	24	8.0	-99.00	-99
07/05/91	22	6.64	22.90	153.70	0.021	-99.000	-0.05	48	25	7.0	-99.00	-99
08/08/91	22	6.80	26.30	162.10	0.027	-99.000	-99.00	45	-99	-99.0	-99.00	-99
11/07/89	23	6.99	18.90	152.20	0.014	-99.000	0.07	43	28	7.0	-99.00	-99
01/08/90	23	7.01	19.50	172.28	0.010	0.500	0.34	32	30	8.0	-99.00	-99
02/13/90	23	6.68	-99.00	173.50	0.017	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
03/13/90	23	6.56	-99.00	161.90	0.018	-99.000	-99.00	24	-99	-99.0	-99.00	-99
04/03/90	23	6.79	12.70	148.10	0.015	0.560	0.39	23	28	-99.0	0.80	3
11/12/90	23	7.25	-99.00	144.90	0.020	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/25/91	23	6.91	16.00	143.50	0.014	0.160	0.39	28	24	10.0	-99.00	-99

Beaver Lake Raw Chemistry Data

Date	Station	pH	Alk	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Fecal
11/07/89	24	6.99	18.40	148.55	0.160	-99.000	0.12	43	27	7.0	-99.00	-99
01/08/90	24	6.89	20.00	172.70	0.013	0.520	0.34	33	30	8.0	-99.00	-99
02/13/90	24	6.61	-99.00	200.90	0.013	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
03/13/90	24	6.50	-99.00	197.80	0.015	-99.000	-99.00	24	-99	-99.0	-99.00	-99
04/03/90	24	6.84	12.60	148.90	0.017	0.590	0.43	24	28	-99.0	0.90	-99
11/12/90	24	7.23	-99.00	144.70	0.017	-99.000	-99.00	-99	-99	-99.0	-99.00	-99
01/25/91	24	6.91	15.70	143.90	0.010	0.190	0.41	29	23	10.0	-99.00	-99

APPENDIX V-4

BEAVER LAKE STORM EVENT

DATE: 8/19/91
STATION: Outlet 1

Sample Number	Time	Turb. (NTU's)	TP (ug/L)	FC (cts/100ml)
1	10:56	0.7	10	170
2	1:30		20	
3	2:00	6.3	32	620
4	2:30	8.0	43	1750
5	3:00	10.4	58	>2000
6	3:30		70	
7	4:00	19	99	>2000
8	4:30		58	
9	5:00	no sample	92	

BEAVER LAKE STORM EVENT

DATE: 8/19/91
STATION: B.L.A.C.

Sample Number	Time	Turb. (NTU's)	TP (ug/L)	FC (cts/100ml)
1	11:03	46.0	213	>2000
2	1:30		251	
3	2:00	424.0	354	>2000
4	2:30		475	
5	3:00	664.0	695	>2000
6	3:30		610	
7	4:00	416.0	545	>2000
8	4:30		237	
9	5:00	149.0	162	>2000

BEAVER LAKE STORM EVENT

DATE: 8/19/91
STATION: Comeau's Beach Brook

Sample Number	Time	Turb. (NTU's)	TP (ug/L)	FC (cts/100ml)
1	11:07	12.2	196	>2000
2	1:30		105	
3	2:00	13.0	154	>2000
4	2:30		138	
5	3:00	20.0	181	>2000
6	3:30		237	
7	4:00	50.0	209	>2000
8	4:30		265	

BEAVER LAKE STORM EVENT

DATE: 8/19/91
STATION: Jenny-Dickey Brook

Sample Number	Time	Turb. (NTU's)	TP (ug/L)	FC (cts/100ml)
1	11:11	22.0	97	>2000
2	1:30		168	
3	2:00	20.0	122	4800
4	2:30		101	
5	3:00	28.0	221	10400
6	3:30		204	
7	4:00	68.0	292	8600
8	4:30		212	
9	5:00	18.0	220	4000

BEAVER LAKE STORM EVENT

DATE: 8/19/91
STATION: Manter Brook

Sample Number	Time	Turb. (NTU's)	TP (ug/L)	FC (cts/100ml)
1	11:16	1.2	28	330
2	1:30		42	
3	2:00	1.4	34	800
4	2:30		33	
5	3:00	1.7	38	1800
6	3:30		36	
7	4:00	8.7	135	2700
8	4:30		116	
9	5:00	3.7	072	3000

DATE: 8/19/91
STATION: Development

Sample Number	Time	Turb. (NTU's)	TP (ug/L)	FC (cts/100ml)
1	11:20	24.0	96	>2000
2	1:30		378	
3	2:00	79.0	184	3700
4	2:30		181	
5	3:00	73.0	160	6000
6	3:30		254	
7	4:00	125.0	290	10 500
8	4:30		096	
9	5:00	12.0	103	1360

BEAVER LAKE STORM EVENT

DATE: 8/19/91
STATION: Cat-O-Brook

Sample Number	Time	Turb. (NTU's)	TP (ug/L)	FC (cts/100ml)
1	11:24	13.2	123	2100
2	1:30		125	
3	2:00	25.0	121	9100
4	2:30		128	
5	3:00	23.0	139	6500
6	3:30		189	
7	4:00	44.0	195	6700
8	4:30		183	
9	5:00	33.0	152	6100

BEAVER LAKE STORM EVENT

DATE: 8/19/91
STATION: Cat-O-Swamp

Sample Number	Time	Turb. (NTU's)	TP (ug/L)	FC (cts/100ml)
1	11:29	8.1	81	6600
2	1:30		90	
3	2:30	3.7	58	9100
4	2:30		66	
5	3:00	5.1	89	7400
6	3:30		85	
7	4:00	5.5	52	11700
8	4:30		120	
9	5:00	15	146	---

APPENDIX VI-1

Beaver Lake Raw Biology Data

Date	Chl-a	Secchi	Dominant Phytoplankton	%	Dominant Zooplankton	Cells/ml
11/07/89	3.48	3.1	DINOBRYON	91	KERATELLA	137.3
					GASTROPUS	45.8
01/08/90	-99.00	-99.0	ASTERIONELLA	95	NAUPLIUS LARVA	
02/13/90	1.82	-99.0	ASTERIONELLA	96	NAUPLIUS LARVA	71.0
					CYCLOPOID COPEPOD	21.8
03/13/90	-99.00	-99.0	ASTERIONELLA	80	NAUPLIUS LARVA	67.6
			MYCROCYSTIS	13	CYCLOPOID COPEPOD	10.9
					BOSMINA	4.4
04/03/90	2.18	3.6	ASTERIONELLA	49	NAUPLIUS LARVA	50.1
			TABELLARIA	26	CYCLOPOID COPEPOD	26.2
			MELOSIRA	15		
05/10/90	3.82	3.6	ASTERIONELLA	94	NAUPLIUS LARVA	125.6
					POLYARTHRA	84.6
					KERATELLA	43.6
06/13/90	6.99	3.4	TABELLARIA	64	NAUPLIUS LARVA	20.0
			MALLAMONAS	9	KERATELLA	14.6
					KELLICOTTIA	12.7
06/28/90	-99.00	4.0	TABELLARIA	57	KELICOTTIA	19.6
			DINOBRYON	14	POLYARTHRA	15.3
			CERATIUM	13		
07/13/90	10.28	4.2	DINOBRYON	36	KELICOTTIA	29.0
			CERATIUM	20	NAUPLIUS LARVA	21.8
			TABELLARIA	15	DAPHNIA	18.2

Beaver Lake Raw Biology Data

Date	Chl-a	Secchi	Dominant Phytoplankton	%	Dominant Zooplankton	Cells/ml
07/27/90	5.21	4.8	CERATIUM	46	KELICOTTIA	21.8
			COELOSPHERUM	20	KERATELLA	17.4
					DAPHNIA	15.3
08/10/90	8.89	3.9	COELOSPHAERIUM	44	KERATELLA	17.4
			OSCILLATORIA	14	POLYARTHRA	17.4
			CERATIUM	13	NAUPLIUS LARVA	15.3
08/24/90	9.24	3.7	OSCILLATORIA	48	NAUPLIUS LARVA	26.2
			COELOSPHAERIUM	21	KERATELLA	21.8
			CERATIUM	20	KELICOTTIA	13.1
09/07/90	6.99	4.4	COELOSPHAERIUM	38	KERATELLA	26.2
			OSCILLATORIA	22	POLYARTHRA	21.8
			CERATIUM	20	KELLICOTTIA	17.4
09/21/90	5.85	4.6	ASTERIONELLA	58	NAUPLIUS LARVA	26.2
			DINOBRYON	11	KERATELLA	24.0
			OSCILLATORIA	10	KELLICOTTIA	24.0
10/05/90	6.97	4.5	COELOSPHAERIUM	45	KELICOTTIA	327.6
			ASTERIONELLA	13	CALANOID COPEPOD	18.0
			CERATIUM	13		
11/12/90	20.78	2.3	SYNURA	86	KELICOTTIA	30.5
					KERATELLA	10.9
01/25/91	-99.00	-99.0	ASTERIONELLA	76	NAUPLIUS LARVA	19.6
					KELICOTTIA	15.3
					KERATELLA	15.3
04/29/91	4.03	3.7	ASTERIONELLA	91	NAUPLIUS LARVA	81.1
					KERATELLA	28.1

Beaver Lake Raw Biology Data

Date	Chl-a	Secchi	Dominant Phytoplankton	%	Dominant Zooplankton	Cells/ml
05/22/91	4.01	2.6	ASTERIONELLA	76	NAUPLIUS LARVA	27.3
					KERATELLA	16.4
06/05/91	9.81	3.9	TABELLARIA	39	KERATELLA	61.0
			DINOBRYON	11	NAUPLIUS LARVA	26.2
07/05/91	-99.00	4.2	CERATIUM	26	KERATELLA	45.8
			COELOSPHAERIUM	14	NAUPLIUS LARVA	34.9
			DINOBRYON	14	CYCLOPOID COPEPOD	26.2
08/08/91	10.31	5.5	CERATIUM	38	KELICOTTIA	131.0
			SYNURA	24	NAUPLIUS LARVA	49.1
			OSCILLATORIA	16	KERATELLA	27.3

APPENDIX VI-2

Beaver Lake Raw Inverted Microscope Phytoplankton Counts

Date	Dominant Phytoplankton	Cells/ml	GROUP DENSITIES							
			Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
11/07/89	CHROOMONAS	293.4	86.0	77.7	0.0	0.0	60.4	405.6	0.0	233.0
	DINOBRYON	120.8								
	CRYPTOMONAS	112.2								
	TOTAL DENSITY	2381.8								
05/10/90	CHROOMONAS	669.6	13.0	259.2	4.3	0.0	345.6	842.4	4.3	116.6
	ASTERIONELLA	194.4								
	TINY FLAGELLATE	190.1								
	TOTAL DENSITY	1585.4								
06/13/90	CHROOMONAS	665.3	8.6	112.3	0.0	13.0	406.1	781.9	0.0	21.6
	CYCLOTELLA/STEPHANO	237.6								
	TOTAL DENSITY	1343.5								
06/28/90	CHROOMONAS	267.8	43.2	159.8	0.0	4.3	263.5	375.8	0.0	17.3
	TABELLARIA	116.6								
	TINY FLAGELLATE	116.6								
	TOTAL DENSITY	864.0								
07/13/90	CHROOMONAS	306.7	90.7	224.6	0.0	0.0	177.1	475.2	21.6	60.5
	CRYPTOMONAS	168.5								
	TOTAL DENSITY	1049.8								
07/27/90	CHROOMONAS	276.5	198.7	164.2	0.0	13.0	25.9	371.5	21.6	30.2
	CRYPTOMONAS	95.0								
	TOTAL DENSITY	825.1								
08/10/90	CHROOMONAS	125.3	164.2	177.1	0.0	21.6	21.6	216.0	8.6	8.6
	CRYPTOMONAS	90.7								
	TOTAL DENSITY	617.8								

Beaver Lake Raw Inverted Microscope Phytoplankton Counts

Date	Dominant Phytoplankton	Cells/ml	Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
			GROUP DENSITIES							
09/07/90	CRYPTOMONAS	125.3	47.5	151.2	0.0	13.0	25.9	237.6	34.6	4.3
	TINY FLAGELLATES	116.6								
	CHROOMONAS	112.3								
	TOTAL DENSITY	488.2								
09/21/90	CHROOMONAS	169.9	80.6	60.5	0.0	0.0	80.6	290.9	5.8	31.7
	CRYPTOMONAS	121.0								
	ASTERIONELLA	66.2								
	TOTAL DENSITY	550.1								
10/05/90	CHROOMONAS	149.0	2.2	142.6	0.0	0.0	10.8	172.8	2.2	23.8
	TINY FLAGELLATES	116.6								
	TOTAL DENSITY	354.2								
11/12/90	SYNURA	144.7	2.2	43.2	0.0	19.4	30.2	60.5	0.0	222.5
	MALLAMONAS	77.8								
	TOTAL DENSITY	378.0								
04/29/91	CHROOMONAS	492.5	0.0	108.0	4.3	0.0	82.1	518.4	0.0	38.9
	TINY FLAGELLATE	95.0								
	TOTAL DENSITY	751.7								
05/21/91	CHROOMONAS	423.4	0.0	13.0	4.3	4.3	388.8	518.4	0.0	25.9
	CYCLOTELLA	237.6								
	ASTERIONELLA	133.9								
	TOTAL DENSITY	954.7								
06/05/91	CYCLOTELLA	149.0	2.2	110.2	4.3	4.3	116.3	175.0	0.0	10.8
	CRYPTOMONAS	110.2								
	TINY FLAGELLATE	69.1								
	TOTAL DENSITY	473.0								

Beaver Lake Raw Inverted Microscope Phytoplankton Counts

Date	Dominant Phytoplankton	Cells/ml	GROUP DENSITIES							
			Blue-Greens	Greens	Desmids	Euglen-oids	Diatoms	Crypto-monads	Dinoflag-ellates	Chryso-phytes
07/05/91	CHROOMONAS	570.2	25.9	146.9	8.6	30.2	56.2	652.3	21.6	99.4
	CRYPTOMONAS	82.1								
	MALLAMONAS	51.8								
	TOTAL DENSITY	1041.1								
08/08/91	SHROEDERIA	724.9	794.0	1001.1	94.9	60.4	60.4	535.1	17.3	34.5
	CHROOMONAS	500.5								
	TOTAL DENSITY	2597.6								

APPENDIX VII-1

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 1

DATE	GAGE HEIGHT	FLOW	STATUS
11/16/89	1.82	12.27	R
11/22/89	1.84	14.24	R
11/29/89	1.92	18.51	R
12/06/89	1.74	6.95	R
12/13/89	1.62	5.60	C
12/19/89	1.58	4.11	C
12/29/89	1.54	2.82	C
01/03/90	1.65	6.85	C
01/17/90	1.58	3.53	R
01/26/90	1.79	7.88	R
02/08/90	1.78	10.45	R
02/22/90	1.72	8.89	R
02/28/90	1.81	19.04	R
03/08/90	1.70	10.26	R
03/15/90	2.00	37.39	R
03/20/90	1.98	36.81	R
03/30/90	1.71	12.25	R
04/13/90	1.80	19.61	R
04/19/90	1.80	19.02	R
04/24/90	1.75	13.65	R
05/01/90	1.76	13.23	R
05/17/90	1.94	31.06	R
05/22/90	1.94	31.24	R
06/01/90	1.80	20.28	R
06/05/90	1.66	11.08	R
06/20/90	1.50	3.17	R
07/06/90	1.54	3.11	R
07/20/90	1.14	0.02	R
08/17/90	1.54	3.01	R
08/30/90	1.78	8.92	R
09/28/90	1.56	1.08	R
10/19/90	2.02	24.29	R
10/26/90	2.10	33.85	R
11/02/90	1.84	17.48	C
11/13/90	2.10	41.54	R
11/20/90	1.82	14.79	R
12/06/90	2.07	36.57	C
12/11/90	1.82	12.61	R
12/17/90	1.92	18.31	R
12/28/90	1.90	19.74	R
01/04/91	1.84	18.22	R
01/18/91	1.92	22.98	R
01/31/91	1.84	17.48	C
04/03/91	1.76	12.73	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 2

DATE	GAGE HEIGHT	FLOW	STATUS
11/16/89	1.12	1.99	R
11/22/89	1.13	2.46	R
11/29/89	1.22	3.06	R
12/06/89	1.01	1.36	R
12/13/89	0.90	1.37	C
12/19/89	0.86	0.92	C
12/29/89	0.81	0.36	C
01/03/90	0.92	1.59	C
01/17/90	0.86	0.34	R
01/26/90	1.07	1.81	R
02/08/90	1.04	2.18	R
02/22/90	1.02	1.70	R
02/28/90	1.10	4.51	R
03/08/90	0.97	1.90	R
03/15/90	1.29	8.29	R
03/20/90	1.29	8.55	R
03/30/90	1.00	2.38	R
04/13/90	1.10	4.44	R
04/19/90	1.08	4.18	R
04/24/90	1.04	2.75	R
05/01/90	1.06	2.83	R
05/17/90	1.24	5.98	R
05/22/90	1.24	6.09	R
06/20/90	0.78	0.55	R
07/06/90	0.81	0.43	R
08/17/90	0.82	0.31	R
08/30/90	1.06	1.32	R
09/13/90	0.86	1.46	R
09/28/90	0.84	0.05	R
10/19/90	1.33	4.78	R
10/26/90	1.42	6.32	R
11/02/90	1.13	3.95	C
11/13/90	1.40	6.91	R
11/20/90	0.92	2.32	R
12/06/90	1.20	4.73	C
12/11/90	0.92	2.19	R
12/17/90	1.03	3.16	R
12/28/90	1.02	3.69	R
01/04/91	0.96	3.09	R
01/18/91	1.04	4.20	R
01/31/91	0.95	1.93	C
04/03/91	0.86	1.84	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 3

DATE	GAGE HEIGHT	FLOW	STATUS
11/16/89	7.25	0.06	R
11/22/89	7.21	0.02	R
11/29/89	7.28	0.04	R
12/06/89	7.16	0.04	C
12/13/89	7.10	0.08	C
12/19/89	7.07	0.12	C
12/29/89	7.02	0.21	C
01/03/90	7.12	0.06	C
01/17/90	-99.00	0.03	R
01/26/90	7.30	0.18	C
02/08/90	7.26	0.02	R
02/22/90	7.29	0.02	R
02/28/90	7.18	0.04	R
03/08/90	7.09	0.01	R
03/15/90	7.34	0.26	R
03/20/90	7.36	0.29	R
03/30/90	7.25	0.48	R
04/13/90	7.09	0.03	R
04/19/90	7.11	0.03	R
04/24/90	7.10	0.02	R
05/01/90	7.14	0.13	R
05/17/90	7.17	1.18	R
05/22/90	7.15	0.08	R
06/01/90	7.11	0.03	R
06/05/90	7.10	0.02	R
06/20/90	7.00	0.26	C
10/19/90	7.29	0.12	R
10/26/90	7.23	0.02	R
11/02/90	7.23	0.07	C
11/13/90	7.32	0.04	R
11/20/90	7.29	0.01	R
12/06/90	7.80	3.19	C
12/11/90	7.27	0.01	R
12/17/90	7.31	0.04	R
12/28/90	7.26	0.04	R
01/04/91	7.24	0.03	R
01/18/91	7.29	0.05	R
01/31/91	7.29	0.16	C
04/03/91	7.28	0.02	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 4

DATE	GAGE HEIGHT	FLOW	STATUS
11/16/89	4.00	0.40	R
11/22/89	11.28	0.13	R
11/29/89	11.35	0.27	R
12/06/89	11.20	0.07	R
12/13/89	11.12	0.05	C
12/19/89	11.12	0.05	C
12/29/89	11.01	-0.12	C
01/03/90	11.05	-0.06	C
01/17/90	11.02	0.06	R
01/26/90	11.47	0.60	C
02/08/90	11.30	0.05	R
02/22/90	11.24	0.10	R
02/28/90	11.29	0.15	R
03/08/90	11.19	0.06	R
03/15/90	11.47	0.47	R
03/20/90	11.45	0.55	R
03/30/90	11.19	0.18	R
04/13/90	11.22	0.19	R
04/19/90	11.25	0.19	R
04/24/90	11.22	0.16	R
05/01/90	11.23	0.32	R
05/17/90	11.40	0.23	R
05/22/90	11.34	0.45	R
06/01/90	11.28	0.20	R
06/05/90	11.24	0.10	R
06/20/90	-99.00	0.00	R
07/06/90	-99.00	0.01	R
09/13/90	-99.00	0.01	R
10/19/90	11.43	0.69	R
10/26/90	11.34	0.16	R
11/02/90	11.28	0.30	C
11/13/90	11.33	0.33	R
11/20/90	11.28	0.14	R
12/06/90	11.34	0.39	C
12/11/90	11.27	0.11	R
12/17/90	11.34	0.15	R
12/28/90	11.31	0.11	R
01/04/91	11.29	0.05	R
01/18/91	11.45	0.44	R
01/31/91	11.47	0.60	C
04/03/91	11.30	0.23	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 5

DATE	GAGE HEIGHT	FLOW	STATUS
11/16/89	5.00	1.61	R
11/22/89	14.49	1.05	R
11/29/89	14.59	2.71	R
12/06/89	14.38	1.30	C
12/13/89.	14.34	0.93	C
12/19/89	14.28	0.36	C
12/29/89	14.16	-0.75	C
01/03/90	14.38	1.30	C
01/17/90	14.24	0.28	R
01/26/90	14.48	2.25	C
02/08/90	14.40	1.13	R
03/08/90	14.40	0.76	R
03/15/90	14.77	4.09	R
03/20/90	14.82	5.68	R
03/30/90	14.38	1.53	R
04/13/90	14.49	1.31	R
04/19/90	14.47	1.50	R
04/24/90	14.41	1.57	R
05/01/90	14.47	3.85	R
05/17/90	14.73	9.36	R
05/22/90	14.65	2.60	R
06/01/90	14.50	0.87	R
06/05/90	14.29	0.31	R
06/20/90	14.14	0.07	R
07/06/90	14.15	0.07	R
08/17/90	14.15	0.06	R
08/30/90	3.94	0.40	R
09/13/90	14.20	0.15	R
09/28/90	14.18	-0.57	C
10/19/90	14.76	10.21	R
10/26/90	14.79	3.43	R
11/02/90	14.47	2.16	C
11/13/90	14.98	2.39	R
11/20/90	15.59	1.17	R
12/06/90	14.94	6.74	C
12/11/90	14.58	1.12	R
12/17/90	14.60	3.03	R
12/28/90	14.57	1.36	R
01/04/91	14.51	1.26	R
01/18/91	-99.00	4.26	R
01/31/91	14.65	3.89	C
04/03/91	14.38	1.32	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 6

DATE	GAGE HEIGHT	FLOW	STATUS
11/16/89	8.13	14.76	R
11/22/89	8.11	12.60	R
11/29/89	8.21	18.48	R
12/06/89	7.89	5.75	C
12/13/89	7.80	3.55	C
12/19/89	7.80	3.55	C
12/29/89	7.86	4.93	C
01/03/90	7.92	6.67	C
01/17/90	7.74	3.45	R
01/26/90	8.06	12.19	C
02/08/90	8.20	10.79	R
02/22/90	7.60	10.69	R
02/28/90	8.20	18.42	R
03/08/90	8.00	11.05	R
03/15/90	8.43	35.18	R
03/20/90	8.52	44.57	C
03/30/90	8.09	14.63	R
04/13/90	8.20	21.00	R
04/19/90	8.19	20.98	R
04/24/90	8.11	16.82	R
05/01/90	8.18	18.15	R
05/17/90	8.37	36.40	R
05/22/90	8.34	32.63	R
06/01/90	8.16	16.62	R
06/05/90	7.99	9.59	R
06/20/90	7.78	4.03	R
07/06/90	7.78	4.27	R
07/20/90	7.60	1.36	R
08/03/90	7.62	1.26	R
08/17/90	7.72	2.55	R
08/30/90	7.91	7.55	R
09/13/90	7.68	2.06	R
09/28/90	7.63	1.67	C
10/19/90	8.36	28.82	R
10/26/90	8.31	27.11	R
11/02/90	8.07	12.66	C
11/13/90	8.38	32.26	R
11/20/90	8.11	14.21	R
12/06/90	8.35	30.06	C
12/11/90	8.09	13.15	R
12/17/90	8.24	22.49	R
12/28/90	8.19	19.04	R
01/04/91	8.14	17.41	R
01/18/91	8.25	23.84	R
01/31/91	8.18	18.53	C
04/03/91	8.70	13.79	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 7

DATE	GAGE HEIGHT	FLOW	STATUS
11/16/89	1.34	0.07	R
11/22/89	1.34	0.05	R
11/29/89	1.34	0.04	R
12/06/89	1.31	0.01	R
12/13/89	1.26	0.07	C
12/19/89	1.25	0.06	C
01/03/90	1.24	0.05	C
01/17/90	1.26	0.08	R
01/26/90	1.56	0.52	C
02/08/90	1.28	0.02	R
02/22/90	1.36	0.11	R
02/28/90	1.32	0.10	R
03/08/90	1.30	0.07	R
03/15/90	1.42	0.27	R
03/20/90	1.41	0.22	R
04/13/90	1.32	0.32	R
04/19/90	1.30	0.12	R
04/24/90	1.29	0.11	R
05/01/90	1.31	0.13	R
05/17/90	1.34	0.15	R
05/22/90	1.30	0.10	R
06/01/90	1.29	1.19	R
06/05/90	1.26	0.06	R
06/20/90	1.24	0.03	R
08/17/90	1.15	0.02	C
08/30/90	1.20	0.04	R
09/13/90	1.16	0.03	C
10/19/90	1.27	0.07	R
10/26/90	1.29	0.11	R
11/02/90	1.28	0.08	C
11/13/90	1.27	0.05	R
11/20/90	1.30	0.22	R
12/06/90	1.29	0.09	C
12/11/90	1.27	0.07	R
12/17/90	1.31	0.11	R
12/28/90	1.28	0.09	R
01/04/91	1.28	0.10	R
01/18/91	1.30	0.11	R
01/31/91	1.29	0.09	C
04/03/91	-99.00	0.08	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 8

DATE	GAGE HEIGHT	FLOW	STATUS
11/16/89	0.44	0.59	R
11/22/89	0.36	0.50	R
11/29/89	0.41	1.12	R
12/06/89	0.31	0.32	C
12/13/89	0.31	0.32	C
12/19/89	0.27	0.28	C
12/29/89	0.25	0.26	C
01/03/90	0.26	0.27	C
01/17/90	0.24	0.43	R
01/26/90	0.77	0.79	C
02/08/90	0.35	0.35	R
02/22/90	0.35	0.23	R
02/28/90	0.44	0.27	R
03/08/90	0.40	0.28	R
03/15/90	0.64	0.66	R
03/20/90	0.58	0.76	R
03/30/90	0.40	0.30	R
04/13/90	0.44	0.46	R
04/19/90	0.42	0.94	R
04/24/90	-99.00	0.53	R
05/01/90	0.44	0.33	R
05/17/90	-99.00	2.12	R
05/22/90	0.48	0.90	R
06/01/90	0.34	0.58	R
06/05/90	0.28	0.13	R
06/20/90	0.36	1.58	R
07/06/90	-99.00	0.05	R
08/03/90	0.76	0.01	R
08/17/90	0.86	0.03	R
08/30/90	0.96	0.17	R
09/13/90	0.92	0.08	R
09/28/90	0.89	0.12	C
10/19/90	1.20	0.69	R
10/26/90	1.22	0.59	R
11/02/90	1.12	0.46	C
11/13/90	1.24	0.67	R
11/20/90	1.12	0.20	R
12/06/90	1.18	0.54	C
12/11/90	1.06	0.47	R
12/17/90	1.10	0.69	R
12/28/90	1.23	0.54	R
01/04/91	1.10	0.38	R
01/18/91	1.09	4.36	R
01/31/91	1.16	0.51	C
04/03/91	1.04	0.29	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 9

DATE	GAGE HEIGHT	FLOW	STATUS
11/16/89	8.95	0.80	R
11/22/89	8.50	0.33	R
11/29/89	9.15	0.68	R
12/06/89	9.15	0.68	R
12/13/89	8.73	1.58	C
12/19/89	8.69	1.56	C
12/29/89	8.65	1.53	C
01/03/90	8.76	1.60	C
01/17/90	6.80	0.43	R
01/26/90	9.00	1.74	C
02/08/90	8.88	1.04	R
02/22/90	-99.00	1.70	R
02/28/90	8.95	1.87	R
03/08/90	8.80	1.57	R
03/15/90	-99.00	3.21	R
03/20/90	-99.00	4.52	R
03/30/90	8.83	2.17	R
04/13/90	-99.00	2.26	R
04/19/90	-99.00	2.03	R
04/24/90	15.22	1.62	R
05/01/90	15.27	2.78	R
05/17/90	15.50	4.42	R
05/22/90	15.46	3.01	R
06/01/90	15.29	1.12	R
06/05/90	15.14	1.65	R
06/20/90	14.92	0.44	R
07/06/90	14.98	0.48	R
07/20/90	14.59	0.03	R
08/03/90	14.60	0.02	R
08/17/90	14.95	0.35	R
08/30/90	15.19	0.90	R
09/13/90	15.30	0.59	R
09/28/90	14.98	0.89	C
10/19/90	15.65	8.60	R
10/26/90	15.60	4.25	R
11/02/90	15.30	2.75	C
11/13/90	15.65	3.90	R
11/20/90	15.31	2.52	R
12/06/90	15.60	5.73	C
12/11/90	15.27	2.30	R
12/17/90	15.41	4.14	R
12/28/90	15.39	3.48	R
01/04/91	15.32	2.54	R
01/18/91	15.44	4.27	R
01/31/91	15.51	4.71	C
04/03/91	15.17	2.36	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 10

DATE	GAGE HEIGHT	FLOW	STATUS
04/13/90	-99.00	0.02	R
04/19/90	-99.00	0.03	R
04/24/90	-99.00	0.04	R
05/01/90	-99.00	0.01	R
05/17/90	-99.00	0.06	R
06/05/90	-99.00	0.02	R
06/20/90	-99.00	0.02	R
08/30/90	-99.00	0.01	R
11/13/90	-99.00	0.02	R
11/20/90	-99.00	0.02	R
12/11/90	-99.00	0.01	R
01/04/91	-99.00	0.05	R
04/03/91	-99.00	0.02	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 11

DATE	GAGE HEIGHT	FLOW	STATUS
07/06/90	-99.00	0.01	R
07/20/90	-99.00	0.01	R
08/17/90	-99.00	0.01	R
09/13/90	-99.00	0.02	R
10/19/90	-99.00	0.35	R
10/26/90	-99.00	0.44	R
11/02/90	-99.00	0.01	R
11/13/90	-99.00	0.32	R
11/20/90	-99.00	0.26	R
12/11/90	-99.00	0.15	R
12/17/90	-99.00	0.29	R
12/28/90	-99.00	0.20	R
01/04/91	-99.00	1.78	R
01/18/91	-99.00	0.18	R
04/03/91	-99.00	0.16	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 12

DATE	GAGE HEIGHT	FLOW	STATUS
12/28/90	-99.00	0.52	R
04/03/91	-99.00	1.18	R

BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

STATION 13

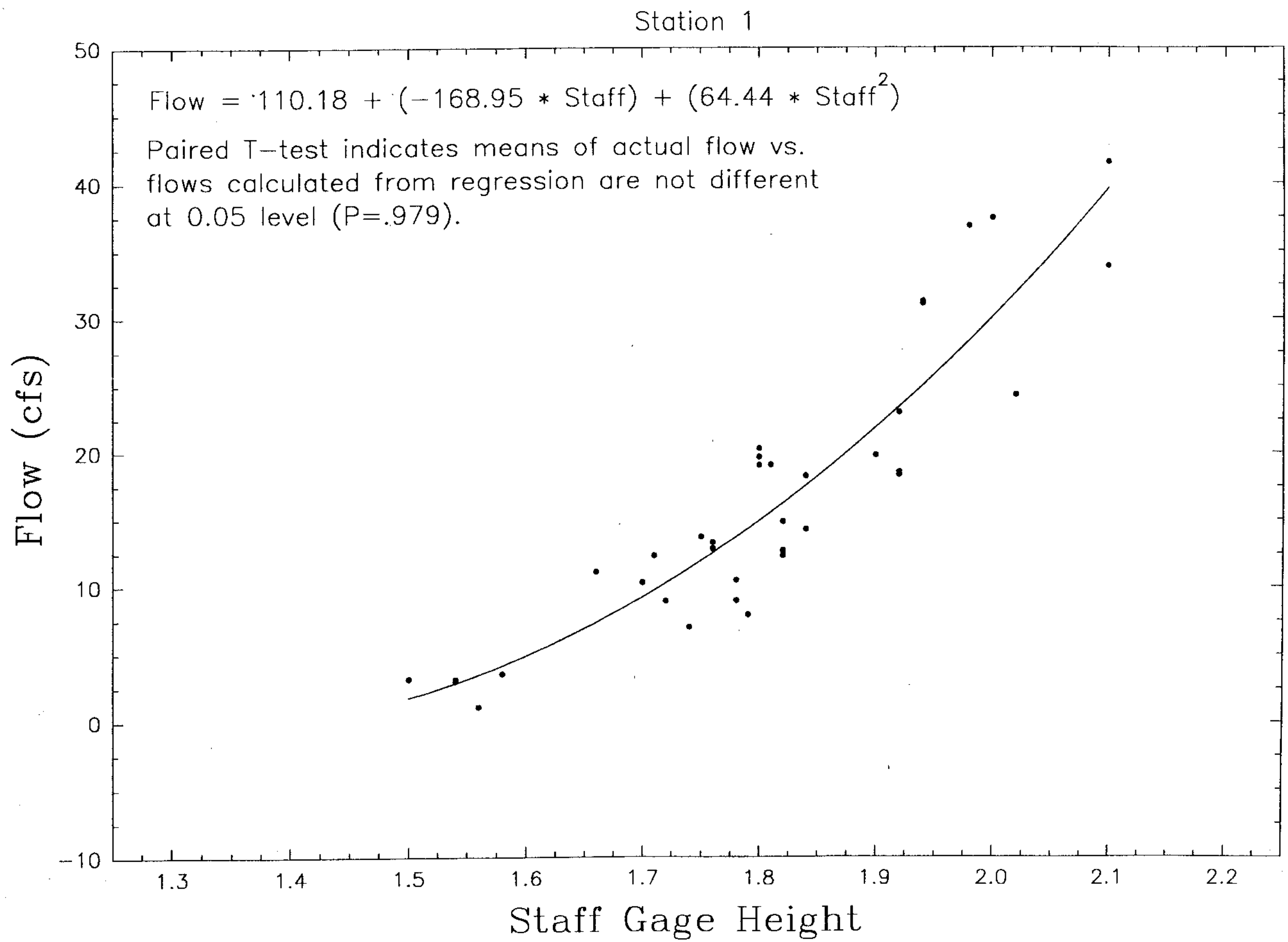
DATE	GAGE HEIGHT	FLOW	STATUS
12/28/90	-99.00	9.72	R
04/03/91	-99.00	5.58	R

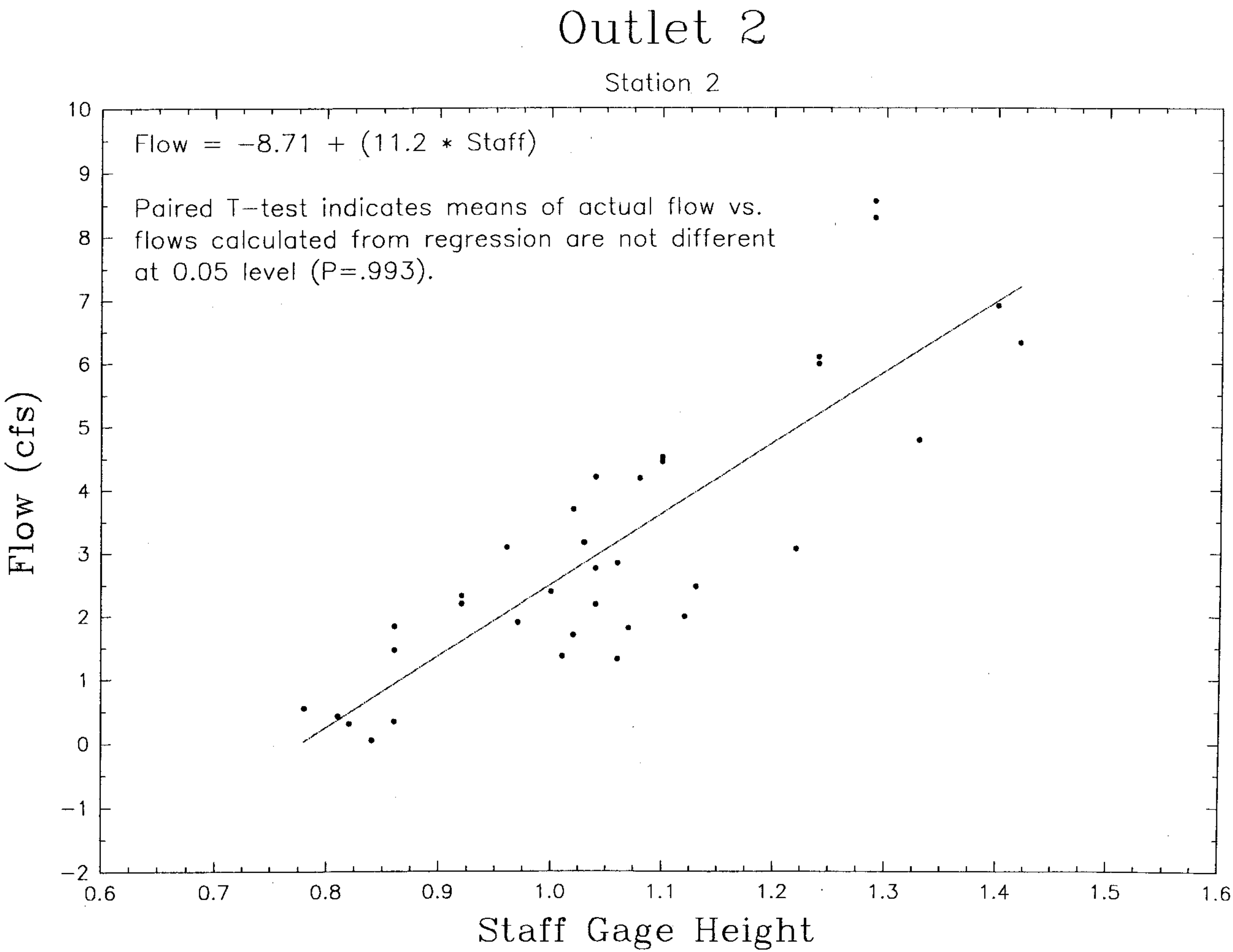
BEAVER LAKE RAW STAFF GAGE AND FLOW DATA

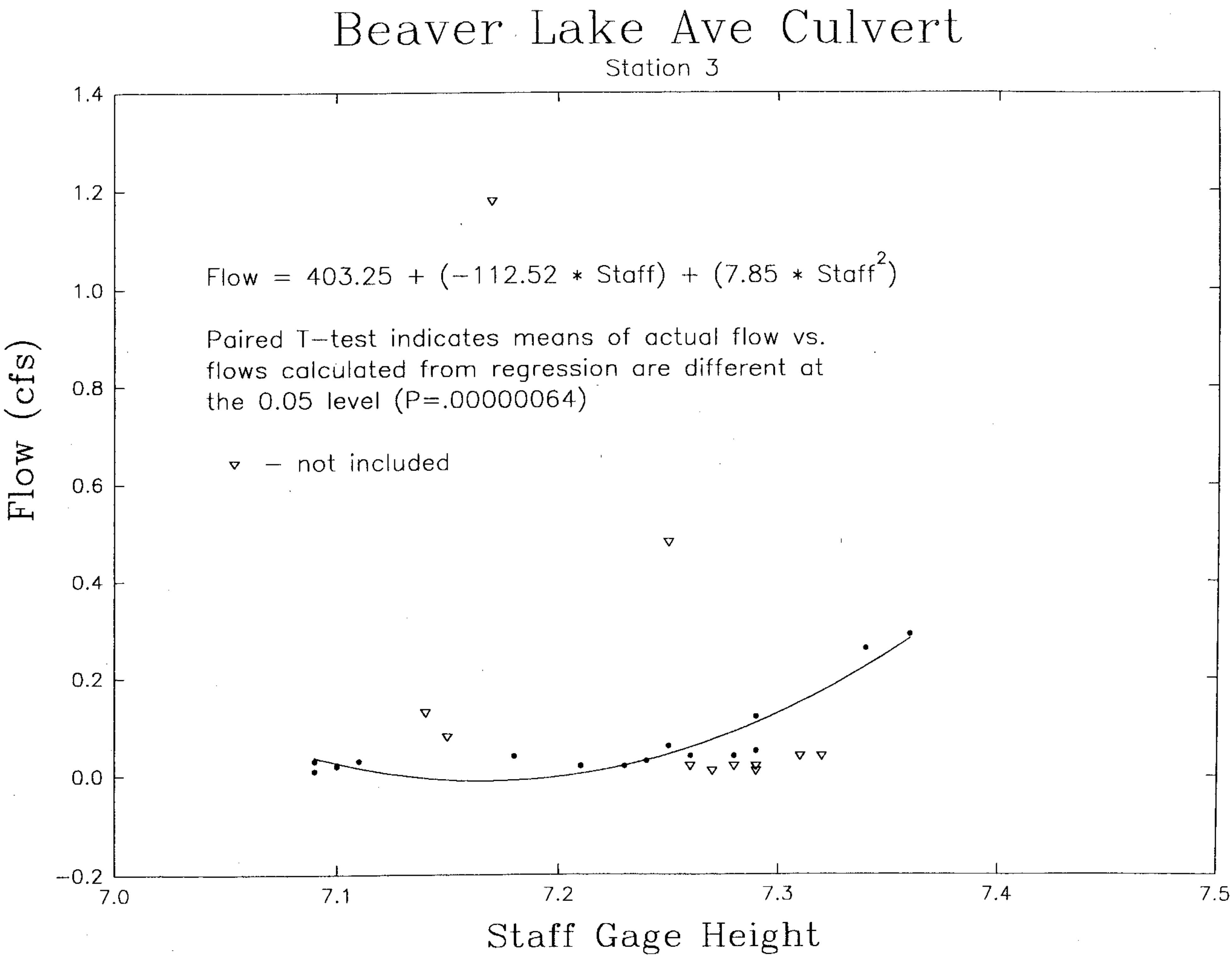
STATION 14

DATE	GAGE HEIGHT	FLOW	STATUS
12/28/90	-99.00	18.06	R
04/03/91	-99.00	13.11	R

Outlet 1

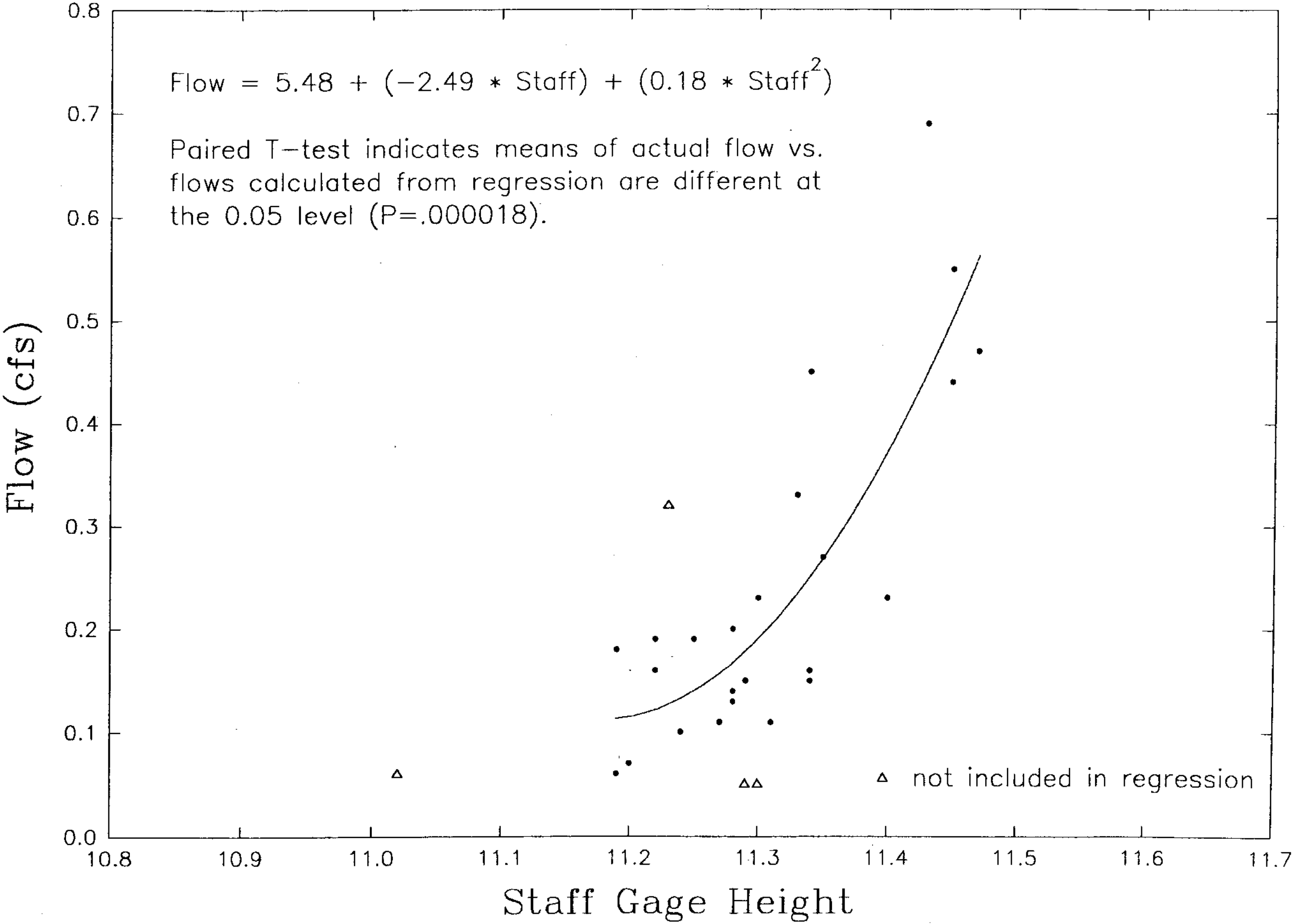

Station 1
Flow = 110.18 + (−168.95 * Staff) + (64.44 * Staff^2)
Paired T−test indicates means of actual flow vs. flows calculated from regression are not different at 0.05 level (P=.979).
50
40
30
20
10
0
−10
Flow (cfs)
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
Staff Gage Height


Outlet 2
Station 2
Flow = −8.71 + (11.2 * Staff)
Paired T−test indicates means of actual flow vs. flows calculated from regression are not different at 0.05 level (P=.993).
Flow (cfs)
Staff Gage Height
10
9
8
7
6
5
4
3
2
1
0
−1
−2
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6


Beaver Lake Ave Culvert
Station 3
Flow = 403.25 + (−112.52 * Staff) + (7.85 * Staff^2)
Paired T−test indicates means of actual flow vs. flows calculated from regression are different at the 0.05 level (P=.00000064)
▽ − not included
Flow (cfs)
Staff Gage Height
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
7.0
7.1
7.2
7.3
7.4
7.5

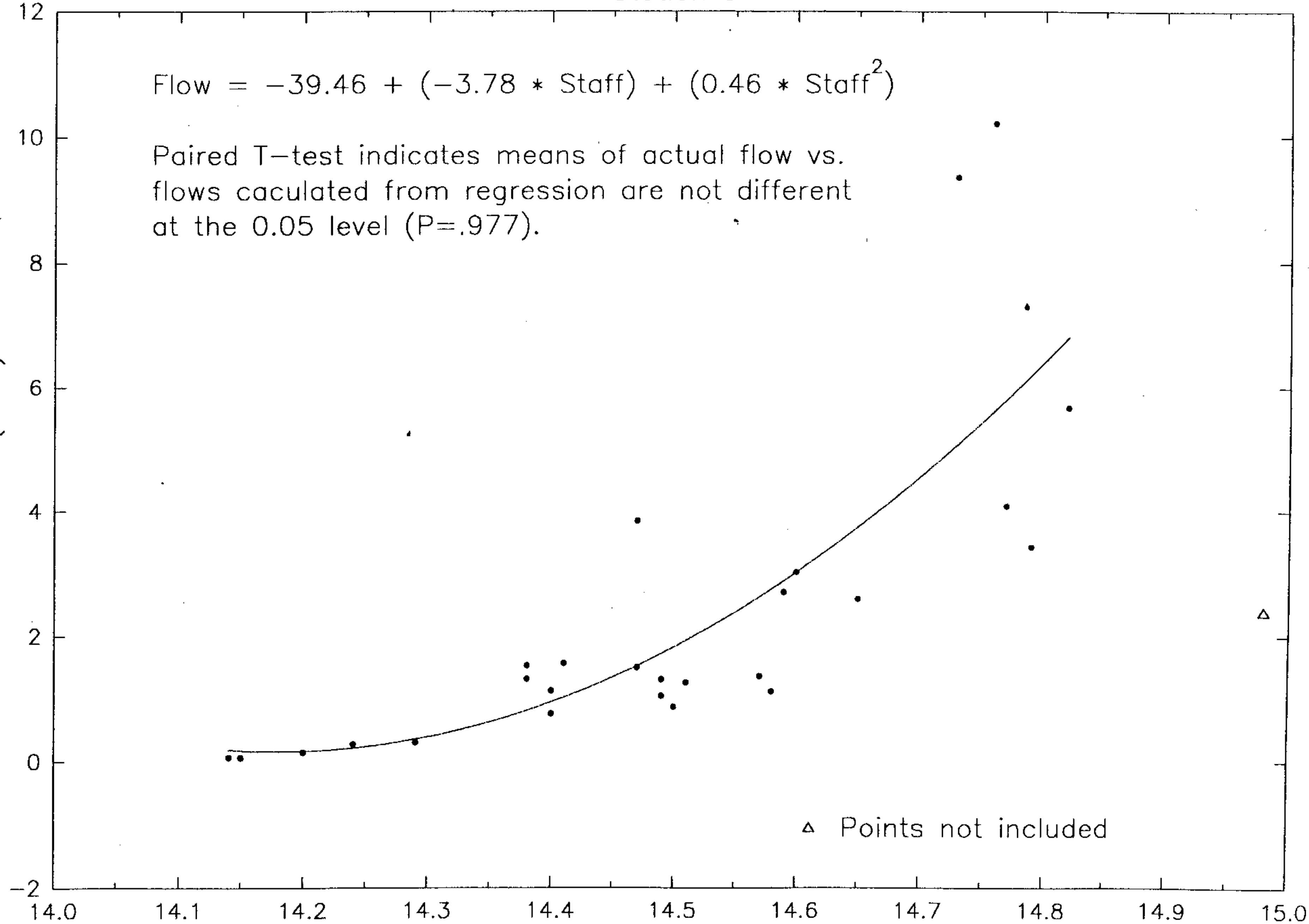
Comeau's Brook

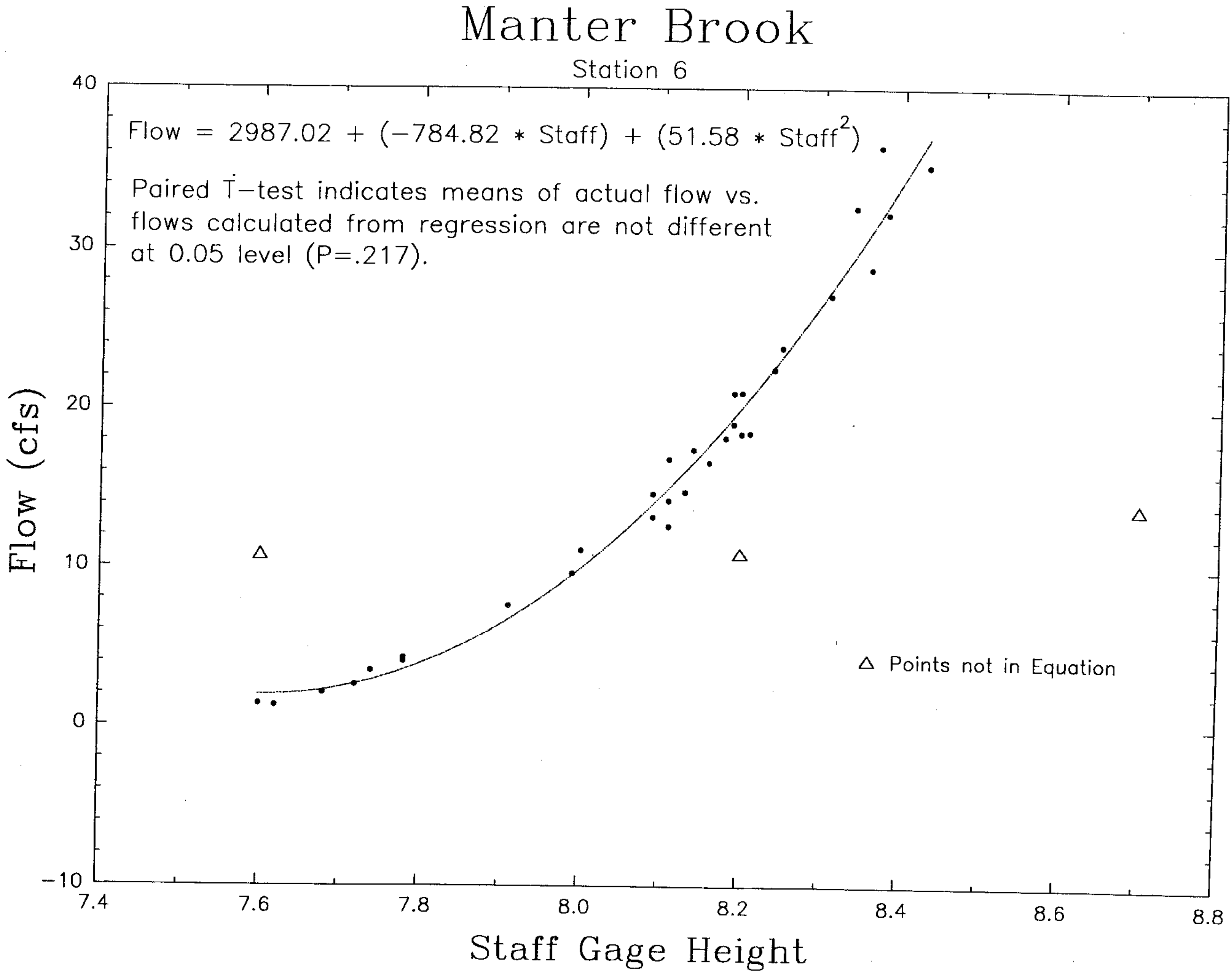
Station 4



Jenney – Dickey

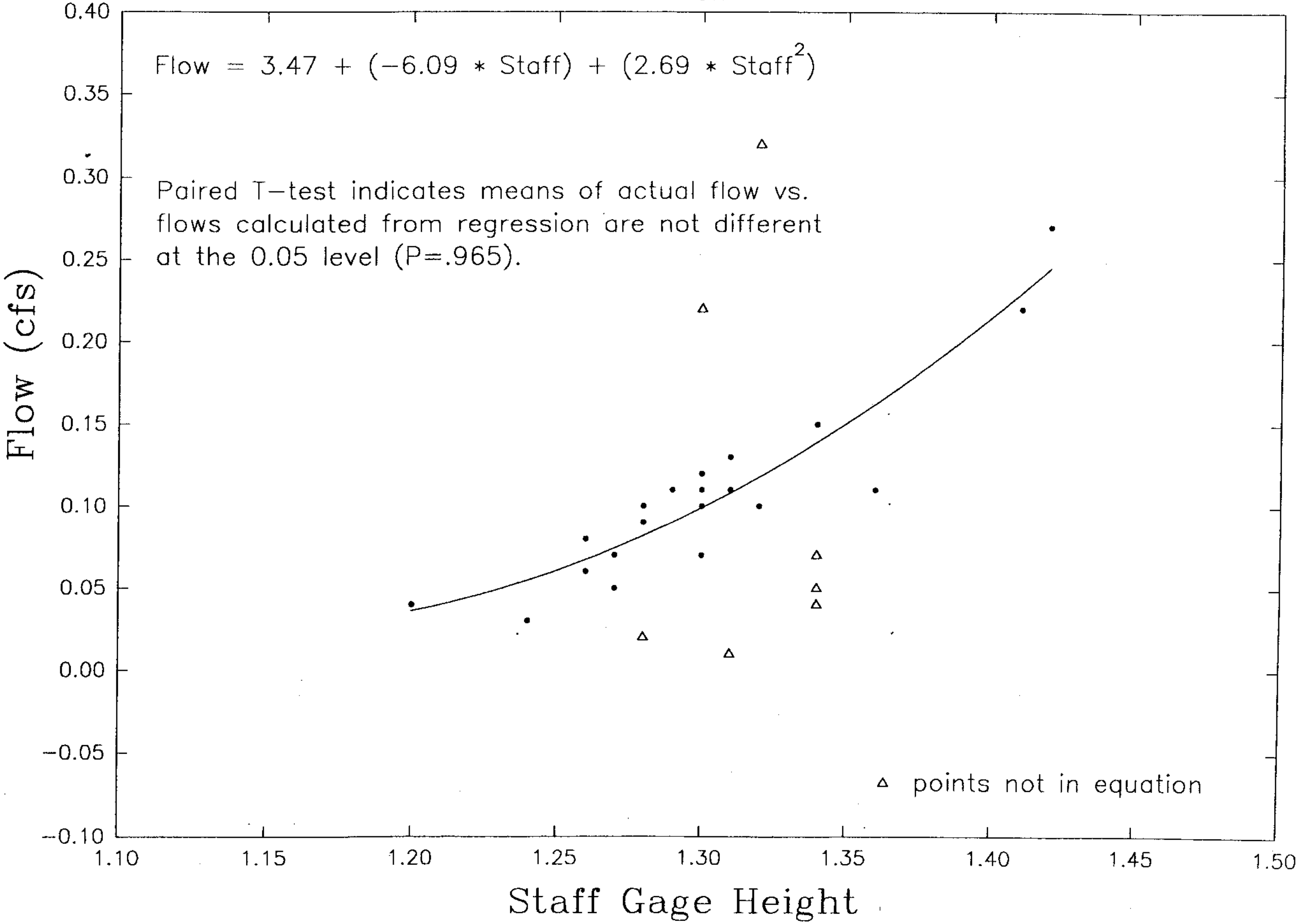
Station 5

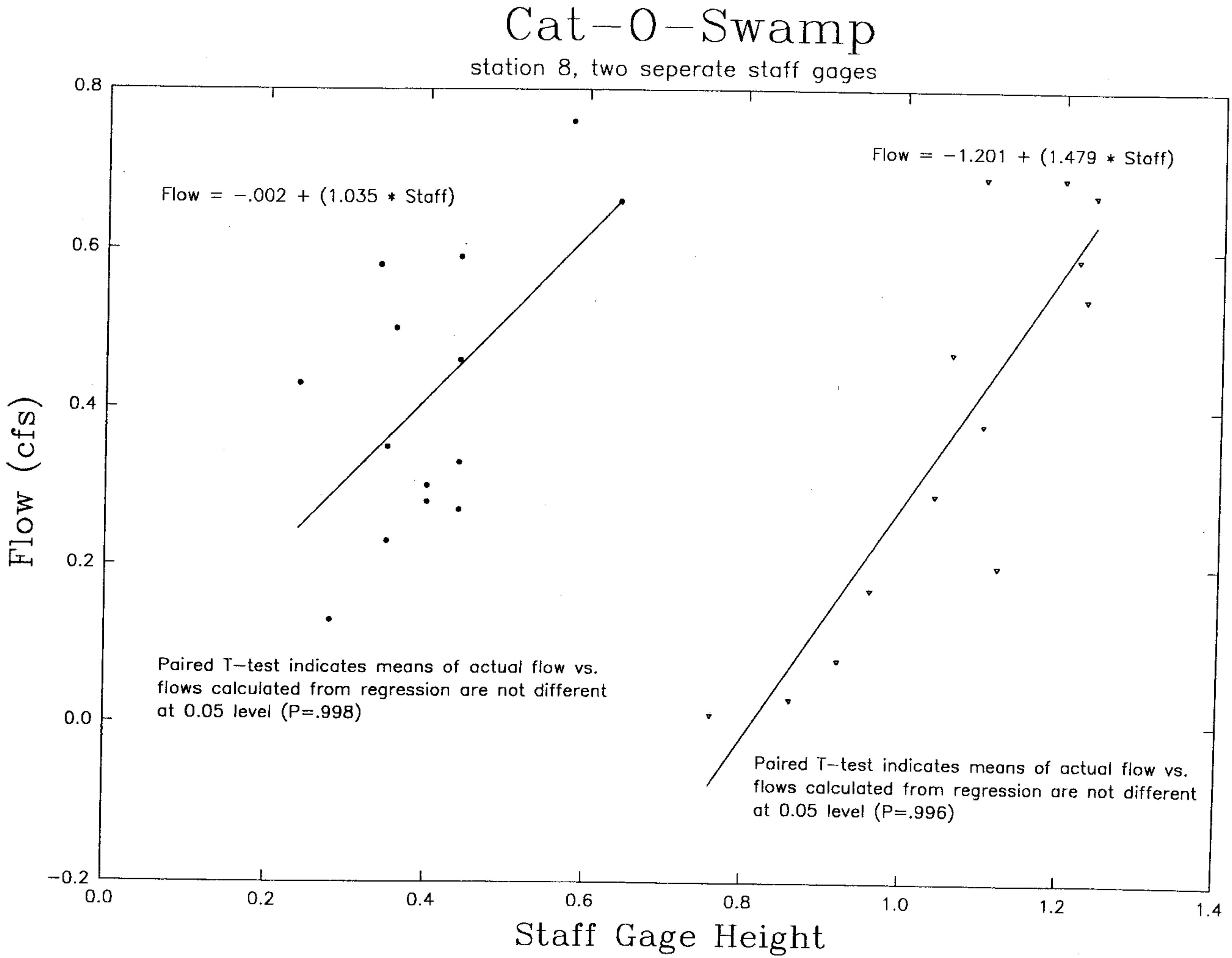



Manter Brook
Station 6
Flow = 2987.02 + (−784.82 * Staff) + (51.58 * Staff²)
Paired T−test indicates means of actual flow vs.
flows calculated from regression are not different
at 0.05 level (P=.217).
Δ Points not in Equation
Flow (cfs)
40
30
20
10
0
−10
7.4
7.6
7.8
8.0
8.2
8.4
8.6
8.8
Staff Gage Height

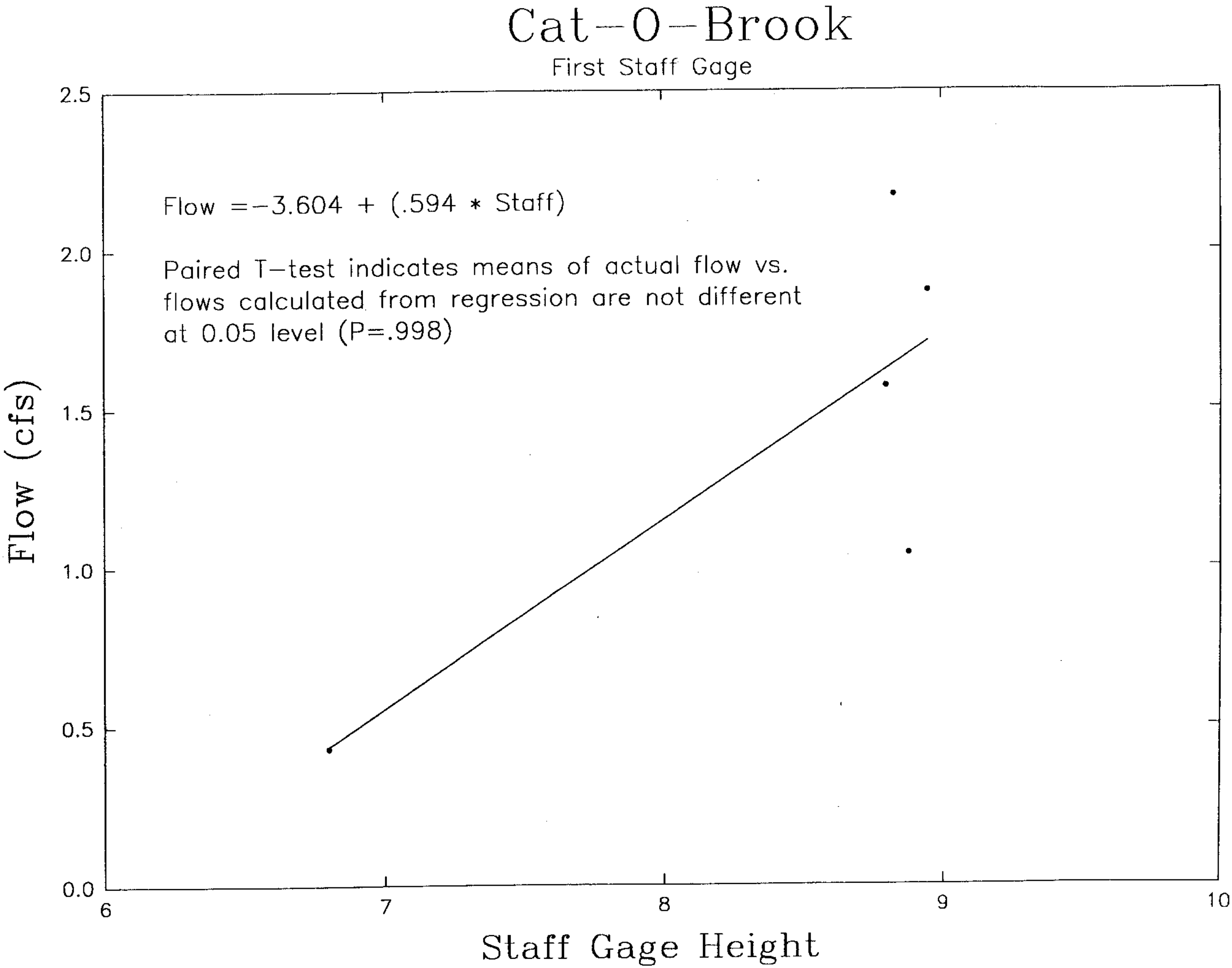
Development Brook

Station 7

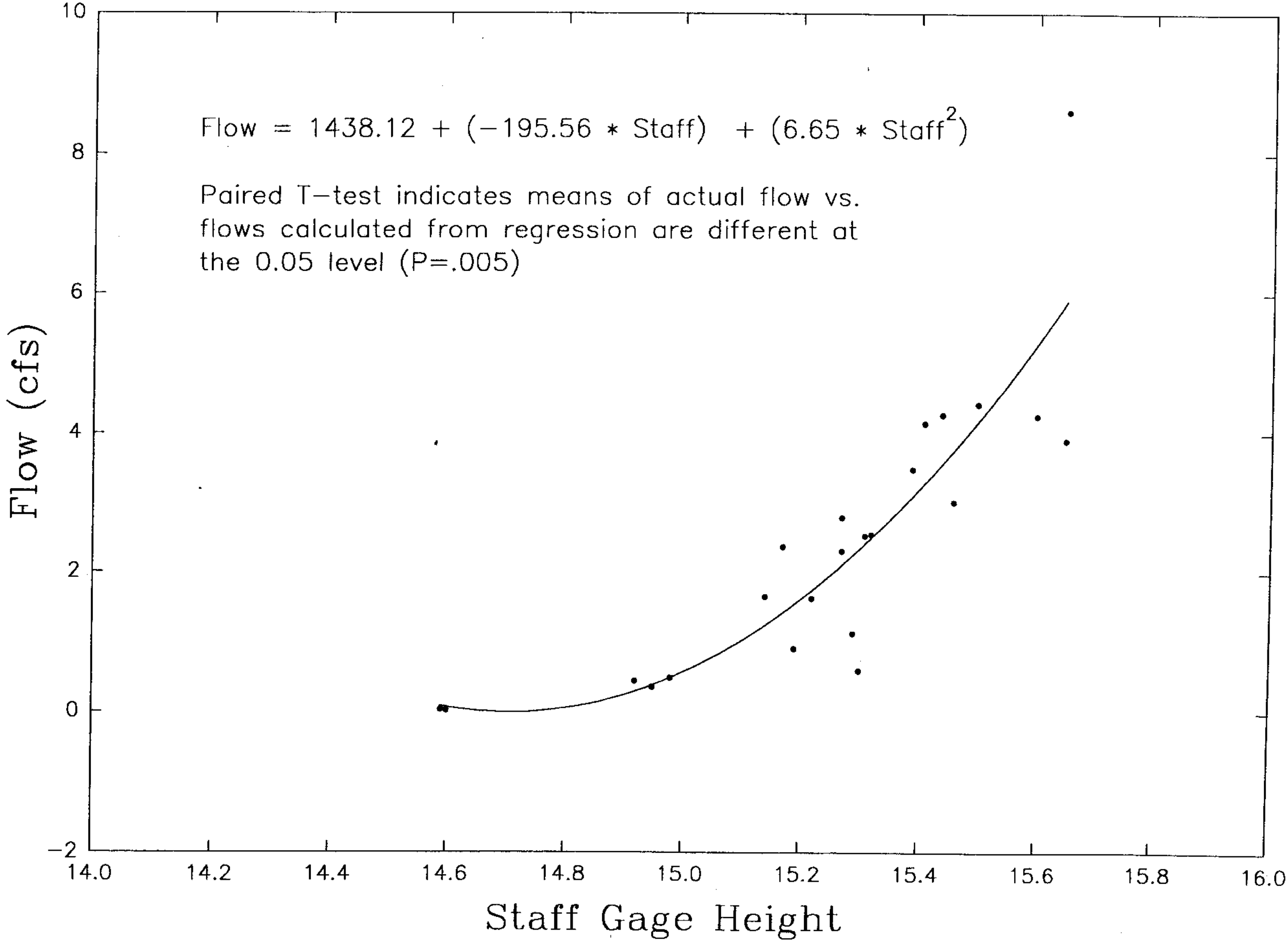




Cat-O-Swamp
station 8, two seperate staff gages
Flow = -.002 + (1.035 * Staff)
Flow = -1.201 + (1.479 * Staff)
Paired T-test indicates means of actual flow vs. flows calculated from regression are not different at 0.05 level (P=.998)
Paired T-test indicates means of actual flow vs. flows calculated from regression are not different at 0.05 level (P=.996)
Flow (cfs)
Staff Gage Height
0.8
0.6
0.4
0.2
0.0
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4


Cat-O-Brook
First Staff Gage
Flow =-3.604 + (.594 * Staff)
Paired T-test indicates means of actual flow vs. flows calculated from regression are not different at 0.05 level (P=.998)
Flow (cfs)
Staff Gage Height
0.0
0.5
1.0
1.5
2.0
2.5
6
7
8
9
10

Cat-O-Brook
Second Staff Gage



APPENDIX VII-2

Beaver Lake Raw Seepage Meter Data

Station	Date	Total Time (min)	Total Volume (ml)	Rate (L/m2)
1	06/28/90	60	95	8.93
1	07/06/90	60	105	9.87
1	07/13/90	60	100	9.40
1	07/20/90	65	75	6.51
1	07/27/90	62	90	8.19
1	08/03/90	61	40	3.70
1	08/10/90	60	65	6.11
1	08/17/90	60	120	11.29
1	08/24/90	60	100	9.40
1	09/07/90	82	55	3.78
1	09/13/90	108	115	6.01
1	09/28/90	94	165	9.90
1	05/21/91	79	57	4.07
1	06/05/91	60	285	26.81
1	06/19/91	60	105	9.87
1	07/17/91	60	250	23.52
2	06/22/90	60	150	14.11
2	06/28/90	60	40	3.76
2	07/06/90	60	154	14.48
2	07/13/90	60	95	8.93
2	07/20/90	65	135	11.72
2	07/27/90	61	175	16.19
2	08/03/90	60	55	5.17
2	08/10/90	60	190	17.87
2	08/17/90	60	210	19.75
2	08/24/90	60	285	26.81
2	09/07/90	80	205	14.46
2	09/13/90	84	230	15.45
2	09/28/90	62	235	21.39
2	05/22/91	73	210	16.23
2	06/05/91	60	150	14.11
2	06/19/91	60	185	17.40
2	07/17/91	60	125	11.76
2	08/08/91	85	95	6.30
3	06/22/90	58	295	28.71
3	07/06/90	60	280	26.34
3	07/13/90	60	180	16.93
3	07/20/90	70	130	10.48
3	07/27/90	60	185	17.40
3	08/03/90	60	55	5.17
3	08/10/90	60	205	19.28
3	08/17/90	60	165	15.52
3	08/24/90	60	275	25.87
3	09/07/90	61	145	13.41
3	09/13/90	72	410	32.14
3	09/28/90	67	205	17.27
3	05/13/91	60	140	13.17
3	05/22/91	76	70	5.19
3	06/05/91	60	80	7.52
3	06/19/91	60	290	27.28
3	07/17/91	60	190	17.87
3	08/08/91	79	90	6.43
4	06/22/90	65	58	5.03
4	06/28/90	60	40	3.76
4	07/06/90	60	120	11.29
4	07/13/90	60	65	6.11
4	07/20/90	80	235	16.58
4	07/27/90	60	30	2.82

Beaver Lake Raw Seepage Meter Data

Station	Date	Total Time (min)	Total Volume (ml)	Rate (L/m2)
4	08/03/90	60	130	12.23
4	08/10/90	60	80	7.52
4	08/17/90	60	120	11.29
4	08/24/90	60	130	12.23
4	09/13/90	60	30	2.82
4	09/28/90	82	45	3.09
4	05/13/91	60	125	11.76
4	05/22/91	73	70	5.41
4	06/05/91	60	50	4.70
4	06/19/91	60	25	2.35
4	07/17/91	63	-40	-3.58
4	08/08/91	80	205	14.46
5	07/13/90	60	37	3.48
5	07/20/90	85	85	5.64
5	07/27/90	60	35	3.29
5	08/03/90	60	30	2.82
5	08/10/90	62	47	4.27
5	08/17/90	60	115	10.81
5	08/24/90	60	105	9.87
5	09/07/90	60	65	6.11
5	09/13/90	61	185	17.12
5	09/28/90	76	105	7.79
5	05/13/91	60	115	10.81
5	05/22/91	75	110	8.27
5	06/05/91	60	100	9.40
5	06/19/91	61	95	8.79
5	07/17/91	60	100	9.40
5	08/08/91	75	660	49.67

APPENDIX VIII-1

APPENDIX VIII-1
Beaver Lake 1st Tier Home Analysis

Lot #	# Bedroom	# Bath's	Heat Yes	Heat No
511	3	1 1/2	X	
512	2	1	X	
513	4	2	X	
514	5	1 1/2	X	
515	2	1	X	
516	3	1	X	
517	2	1	X	
518	1	1	X	
519	1	1	X	
5022	2	1	X	
5022-1	no home	non-buildable		X
5023	3	1 1/2	X	
5025	4	2	X	
5026	no home	vacant		
5027	2	1		X
5028	3	1		X
5031	2	1/2		X
5032	boat launch	vacant		
0990-1	3	1	X	
*0943-2-1	3	2	X	
521	4	1	X	
522	2	1	X	
523		BLA park		

APPENDIX VIII-1
Beaver Lake 1st Tier Home Analysis

Lot #	# Bedroom	# Bath's	Heat Yes	Heat No
561			vacant	
562	4	1	X	
563			vacant	
564			vacant	
565	3	2	X	
566	3	1	X	
567			vacant	
568	2	2	X	
569	3	1	X	
5110	3	1	X	
5111	2	1	X	
5112	2	1	X	
5113	2	1	X	
5114	1	0		X
5115	3	1	X	
5116	2	1	X	
5117	3	1	X	
5119	2	1	X	
5120			no buildings	
5121	2	1		X
5122	2	1	X	
5123	2	1	X	
5124	3	1		X
5148	4	2	X	

APPENDIX VIII-1
Beaver Lake 1st Tier Home Analysis

Lot #	# Bedroom	# Bath's	Heat Yes	Heat No
5149	3	1		X
5150	1	1		X
5151	3	1		X
5151-1	2	1		X
5152	4	1	X	
5153	2	1		X
5154	2	1		X
5156	3	1	X	
5157	2	0		X
5158	3	1	X	
5159	2	1	X	
5160	2	1		X
5161	2	1	X	
5162	2	1/2		X
5166	2	1/2		X
5167	4	2	X	
5168	2	1		X
5171	2	1	X	
5172	4	1/2		X
5173	4	2	X	
5175	1	1	X	
5176	1	1	X	
5177	3	1	X	
5177-1	2	1	X	

APPENDIX VIII-1
Beaver Lake 1st Tier Home Analysis

Lot #	# Bedroom	# Bath's	Heat Yes	Heat No
5178	3	1		X
5179	2	1		X
5180	2	1	X	
5181	2	1		X
5182	3	1	X	
5183	2	1	X	
5184	Beaver Lake	Beach		
5523	3	1 1/2		X
5524				
5525	3	1 1/2	X	
5526	2	1	X	
5527	4	2	X	
5528	4	2	X	
5529	2	1		X
5530	3	1	X	
5532				
5533	2	1 1/2		X
5534	1	1	X	
5545	3	2	X	
5546	5	2	X	
5547	no building			
5548	4 cottages			
	2	2	X	

APPENDIX VIII-1
Beaver Lake 1st Tier Home Analysis

Lot #	# Bedroom	# Bath's	Heat Yes	Heat No
5549	3	1	X	
5550	1	1	X	
5551	3	1	X	
5552	1	1	X	
5553	vacant			
5554	2	1	X	
5555	2	1	X	
5041			no home	
5046			no home	
5047	2	1	X	
5048			no home	
5246			no home	
5559			no home	
5633	2	1	X	
5612	3	1	X	
5613	2	1	X	
5614	3	0		X
5619	4	2	X	
5619-1			vacant	
5619-2			vacant	
5619-10			vacant	
5619-11			vacant	
5619-12			vacant	
5620	2	1	X	

APPENDIX VIII-1
Beaver Lake 1st Tier Home Analysis

Lot #	# Bath's	# Bedroom	Yes	No
5621	2	1	X	
5622				
5623	3	1/2		X
5624	2	1	X	
5625	2	1	X	
5626	3	1 1/2	X	
5627	2	1		X
5628	2	1	X	
5629	3	1		X
5630	2	1	X	
5631				
5632	2	1		X
5610	2	1 1/2	X	
5648	2	1	X	
5649	2	1 1/2	X	
5649-1	2	1 1/2	X	
5649-2	2	1	X	
5654	3	1	X	
5654-1	3	1	X	
5655	4	1		X
5656	2	1		X
5657	2	1		X
5657-1			none	
5658	2	1	X Heat	

APPENDIX VIII-1
Beaver Lake 1st Tier Home Analysis

Lot #	# Bedroom	# Bath's	Yes	No
5659	3	1	X	
5660	4	3	X	
5668	2	1	X	

APPENDIX VIII-2

BEAVER LAKE RAW DUG WELL DATA

	Date	Tp (mg/L)
Well 1		
	06/22/90	0.002
	09/13/90	0.013
Well 2		
	06/22/90	-0.001
	08/17/90	-0.001
Well 3		
	04/14/90	0.005
	05/31/90	0.011
	07/20/90	0.018
	07/19/91	0.011
Well 4		
	04/14/90	0.012
	09/13/90	0.014
Well 5		
	04/14/90	0.033
	05/31/90	0.028
	07/20/90	0.028
	09/28/90	0.022
	07/19/91	0.046
Well 6		
	04/14/90	0.015
Well 7		
	04/14/90	0.014
Well 8		
	06/13/90	0.003
	08/03/91	0.009
Well 9		
	06/13/90	0.008
Well 10		
	06/13/90	0.003
	07/27/90	0.001
	08/17/90	-0.001
Well 11		
	04/14/90	0.018
	05/31/90	0.027
Well 12		
	07/27/90	0.011
Well 13		
	08/03/90	0.005
Well 14		
	07/27/90	0.003

APPENDIX VIII-3

Beaver Lake IPWS Raw Data

Station	Date	Tp	Cond
1	06/28/90	0.070	-99.00
1	07/13/90	0.203	-99.00
1	07/20/90	0.049	-99.00
1	08/03/90	0.067	-99.00
1	08/10/90	0.125	-99.00
1	08/17/90	0.129	-99.00
1	08/24/90	-9.900	1.19
1	08/24/90	0.141	119.20
1	09/13/90	0.092	763.60
1	09/28/90	0.043	510.00
1	05/21/91	-9.900	472.00
1	06/19/91	0.360	-99.00
1	07/17/91	0.087	422.00
2	06/22/90	0.955	-99.00
2	06/28/90	0.265	-99.00
2	07/13/90	0.290	-99.00
2	07/20/90	0.149	-99.00
2	08/03/90	0.101	-99.00
2	08/10/90	0.175	-99.00
2	08/17/90	0.072	-99.00
2	08/24/90	-9.900	454.50
2	08/24/90	0.042	454.50
2	09/13/90	0.059	513.00
2	09/28/90	0.017	689.00
2	05/22/91	0.099	122.40
2	06/19/91	0.079	-99.00
2	07/17/91	0.063	112.90
2	08/08/91	0.124	107.10
3	06/22/90	0.475	-99.00
3	06/28/90	0.108	-99.00
3	07/13/90	0.168	-99.00
3	07/20/90	0.187	-99.00
3	08/03/90	0.079	-99.00
3	08/08/90	0.143	161.80
3	08/10/90	0.106	-99.00
3	08/17/90	0.105	-99.00
3	08/24/90	-9.900	210.00
3	08/24/90	0.054	210.00
3	09/13/90	0.048	193.80
3	09/28/90	0.058	189.00
3	05/22/91	0.118	113.07
3	06/19/91	0.108	-99.00
3	07/17/91	0.080	162.70
3	08/08/91	0.143	161.80
4	06/22/90	0.238	-99.00
4	06/28/90	0.425	-99.00
4	07/13/90	0.392	-99.00
4	07/20/90	0.257	-99.00
4	08/03/90	0.318	-99.00
4	08/10/90	0.322	-99.00
4	08/17/90	0.151	-99.00
4	08/24/90	-9.900	328.50
4	08/24/90	0.466	328.50
4	09/13/90	0.104	23.15
4	09/28/90	0.328	314.00
4	05/22/91	0.373	287.10
4	06/19/91	0.212	-99.00
4	07/17/91	0.208	259.10
4	08/08/91	0.244	300.18
5	07/20/90	0.088	-99.00

Beaver Lake IPWS Raw Data

Station	Date	Tp	Cond
5	08/03/90	0.084	-99.00
5	08/10/90	0.151	-99.00
5	08/17/90	0.132	-99.00
5	08/24/90	-9.900	122.80
5	08/24/90	0.098	122.80
5	09/13/90	0.092	152.95
5	09/28/90	0.073	149.00
5	05/22/91	0.081	88.60
5	06/19/91	0.046	-99.00
5	07/17/91	0.386	112.70
5	08/08/91	0.090	134.80

APPENDIX XI-1

Section 3 - No junk yard or place for the storage of discarded machinery, vehicles, or other materials shall be permitted.

Section 6 - No permit shall be granted for the construction of or placement of a building or dwelling on a lot in any zone unless said lot shall comply with the following requirements:

a. As used in this section, a residential lot shall be defined as a lot or parcel of land on which a single family dwelling, duplex dwelling (any two-family dwelling, consisting of two dwelling units), or mobile home is located, including lots for placement within Mobile Home Parks. (Effective 10/8/87)

b. Except as set forth elsewhere in this ordinance, all lots WITHOUT Town sewer shall contain a minimum area of one acre per dwelling unit with a width of at least 125' at the 35' setback line from the street or on the road and all lots WITH Town sewer shall contain a minimum of 30,000 square feet per swelling unit with a width of at least 125' at the 35' setback line from the street or on the road. However, this requirement shall not be applicable to any legally existing or approved lot containing at least 25,000 square feet with a width of 125' at the 35' setback line from the street or on the road, provided said lot meets the requirements for the State Water Supply and Pollution Control Commission (WSPCC). (Effective 10/8/87)

c. (1) In the Multi-Family Residential Zone only, residential lots where municipal water or municipal sewer are available, shall contain a minimum of 15,000 square feet with a width of at least 100' at the 35' setback line from the street or on the road. Residential lots where community water systems are available, must contain a minimum of one acre (43,560 sq. ft.) with a width of at least 125' at the 35' setback line or on the road. (Effective 10/8/87)

d. Only one residential building or dwelling shall be situated on a lot.

e. Each residential lot must face on an approved street.

f. All building or dwellings shall be set back with a minimum of Thirty-Five (35') feet from the street line or to conform with the average setback of the structures. Three Hundred (300') feet from either side of the building on the same side of the street. Side and back line setback shall be a minimum of Fifteen (15') feet.

g. No commercial or industrial building shall be constructed or placed on a lot smaller than that required for dwelling.

h. Buildings or business not connected to public sewer shall require 10,000 square feet of lot size above the minimum for the zone for each 200 gallons per day of sewage effluent after the first 200 gallons per day unless the owner can show adequate plans for sewage disposal on a smaller lot.

i. Any business built or expanded after the date of this ordinance shall have adequate off-street parking of employees and customers on land in the same title as the business property.

j. All Duplex dwellings shall be located in the Multi-Family residential zone. (Effective 10/8/87)

k. Creation of an existing single family dwelling shall be subject to the following conditions:

1. The lot on which the building is situated must have the minimum area for the zoning district in which it is located.
2. Where municipal sewer is not provided the owner shall have written approval from N.H. Water Supply & Pollution Control Division that the septic system meets the requirements for the combined use.
3. Off-street parking shall be provided for at least four (4) vehicles.
4. The existing structure cannot be increased more than ten percent (10%) of the total floor area.
5. The additional dwelling unit cannot exceed four hundred square feet (400 s.f.), nor can the existing dwelling be reduced to less than eight hundred square feet (800 s.f.).
6. The additional dwelling unit must be attached to the existing dwelling.
7. No conversion of independent free standing structures for an additional dwelling unit will be allowed.
8. No additional expansion of a dwelling with an existing attached structure will be allowed for the creation of an additional dwelling unit.
9. Room sizes must conform to the minimum requirements CABA One & Two Family Dwelling Code.
10. The additional dwelling unit shall be composed of and limited to kitchen, living room, one bedroom, and a bathroom.
11. The structure and lot shall not be converted to a condominium or any other form of legal ownership distinct from the ownership of the existing single-family. The additional dwelling use shall be recorded by deed addendum.
12. An additional dwelling unit shall not be allowed in conjunction with any other exception.
13. An additional dwelling unit shall not be permitted in conjunction with a variance from any requirement of Article II, Section 6. (New Item 'k' -Effective 3/7/91)

APPENDIX XI-2

Section 5 - DEFINITIONS

A. DISTRICT BOUNDARIES

1. Establishment of a District. - The limits of the Wetlands Conservation District are hereby determined to be the following:

a. All areas of very poorly drained soils.
b. Areas of poorly drained soils, 2,000 sq. ft. or more in size, and that exhibit a predominance of 50% or more wetland vegetation.
c. Areas of any wetland of any size if contiguous to surface waters such as lakes, pond and streams.
d. Areas designated as bogs regardless of any size.

B. PRIME WETLANDS shall be defined as those areas designated Prime Wetlands within the scope of RSA 483-A, and N.H. Code of Administrative Rules WT700. These wetlands are described in the Derry Prime Wetlands Report dated November 11, 1986. The topographic definition of each prime wetland is included in separate maps correlated to the report. Both the aforementioned maps and report are incorporated in this ordinance by reference.

C. PRIME WETLANDS BUFFER ZONE shall be defined as that area extending One Hundred Fifty (150') feet beyond the boundary of each prime wetland as described in Definition "B" above.

D. POORLY DRAINED SOILS shall be defined as soils with a moderately high water table as described in the report entitled: Soils Information for Resource Planning for the Town of Derry, dated March, 1980, or as further defined by "High Intensity Soils Maps for N.H." on file with the Rockingham County Conservation District.

E. VERY POORLY DRAINED SOILS shall be defined as soils with a permanent high water table as described in the report entitled: Soils Information for Resource Planning for the Town of Derry, dated March, 1980, or as further define by "High Intensity Soils Maps for N.H." on file with the Rockingham County Conservation District.

F. WETLANDS are areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support and that under normal conditions do support a prevalence of vegetation typically adapted for life in saturated soil conditions. They include, but are not limited to, swamps, bogs, marshes, ponds, lakes as well as soils that are defined as poorly or very poorly drained.

G. SWAMPS contain predominantly woody vegetation (shrubs and trees) and range in wetness from occasionally flooded to standing water most of the year; or as further defined by the N.H. Wetlands Board.

H. BOGS are highly acidic wetlands that have usually developed in undrained glacial depressions and are generally underlaid by thick layers of saturated organic soils called peat; or as further defined by the N.H. Wetlands Board.

I. MARSHES (FRESHWATER) are characterized by herbaceous (soft-stemmed) vegetation, or as further defined by the N.H. Wetlands Board.

J. HIGH INTENSITY SOIL MAPS FOR NEW HAMPSHIRE - The most recent document prepared by the Society of Soil Scientists of Northern New England detailing the standard for making high intensity soils maps. On file with the Rockingham County Conservation District.

K. QUALIFIED SOIL SCIENTIST - A person qualified in soil classification and mapping who is recommended or approved by the New Hampshire State Conservation Committee.

Section 6 - INCORRECTLY DESIGNATED ZONES

When a boundary of the Wetland Conservation District is disputed, or in the event that an area is incorrectly designated as being poorly drained or very poorly drained soils on the "U.S. Department of Agriculture, Soil Conservation Service, Town of Derry, Rockingham County, New Hampshire, Soil Survey, March 1980", map; the Planning Board and/or the Conservation Commission, at the applicants' expense may engage a professional biologist and/or soils scientist qualified in field analysis to determine the precise location of the Wetland

Conservation District boundaries in the properties affected. A report of their findings shall be submitted to the Planning Board and shall include, but not be limited to, a revised soils map of the area in question prepared by a qualified soils scientist, along with a written report.

The planning Board shall adjust the boundary of this district, if necessary, based on the evidence provided as set forth above. If the evidence indicates that the boundary or area in question has been incorrectly designated, the restrictions contained in this section shall not apply. Conversely, in the event that an area has poorly drained or very poorly drained soils within the meaning of the aforementioned definitions, then the restrictions contained in this section shall apply. The Planning Board shall reserve the right to withhold action on any plot pending the results of an on-site inspection by the Board or its appointed agent.

C. Special Exception

The hearing for the special exception shall require a joint meeting of the Zoning Board of Adjustment, Planning Board and the Conservation Commission, provided there is a significant and substantial impact to the productive use of the land defined as landlocked or unbuildable lots caused by the creation of the Prime Buffer Zones.

Upon application to the Board of Adjustment, a special exception shall be granted for uses in the outermost Seventy-Five (75') feet of the Prime Wetland buffer zones provided that all of the following conditions are found to exist:

1. The proposed special exception is essential to the productive use of land not within the Prime Wetland Buffer Zone.
2. Design and construction methods will be such as to minimize detrimental impact upon the Prime Wetland, the Seventy-Five (75') feet buffer nearest the Prime Wetland, and the site will be restored as nearly as possible to its original condition.
3. Economic advantage alone is not reason for the proposed construction.
4. The use for which the exception is sought cannot feasibly be carried out on a portion or portions of the lot which are outside the Prime Wetland Buffer Zone.

5. The design and construction of the proposed use will, to the extent practical, be consistent with the purpose and intent of this Article.
6. The proposed use will not create a hazard to individual or public health, safety and welfare due to the loss of the Prime Wetland Buffer Zones, the contamination of ground water, or other reason.
7. Any special exception granted shall not disturb the Seventy-Five (75') feet of the Prime Wetland Buffer Zones nearest the Prime Wetland.
8. When a parcel is being developed no landlocked land or unbuildable lot shall be created that would require a special exception or variance under this Article.
9. Studies/reports that may be required:
    a. Botanist.
    b. Biologist.
    c. Soil Scientist.
    d. Sediment/Erosion Control Plan.
    e. Impact on the wetland, water quality and habitat.
    f. Appropriate escrow shall be established for construction and inspection.
    g. Drainage calculations.
    h. Amount of area to be disturbed.

No Special exception shall be granted in the Prime Wetlands. No dredging and filling shall be permitted in the Prime Wetlands.

D. <u>Pre-existing Use in the Prime Wetland Buffer Zone</u>

1. Structures and uses existing at the time of the adoption of this ordinance may be continued.

2. Where an existing use within the buffer is destroyed or in need of extensive repair it may be rebuilt provided that such rebuilding is completed within one year of the event causing destruction and the new or rebuilt use shall not extend further into the buffer area than the original use.
3. Expansion of an existing use shall require a permit from the Code Enforcement Officer (CEO).

4. The application for a permit shall be accompanied by two copies of a drawing of the proposal prepared to scale or so dimensions are clearly defined. One copy shall be retained by the CEO and one copy shall be forwarded (by the CEO) to the Conservation Commission, a minimum of 5 working days prior to the issuance of permit.

5. If the proposed use, or expansion of use, is found to be detrimental to any function of the wetland the CEO shall not issue the permit.

E. Exemption for Residential Structures

Notwithstanding other provisions of this Article, the construction of additions and extensions to one and two family dwellings shall be permitted within the buffer zone provided that:

1. The dwelling lawfully existed prior to the effective date of this Article. (2-4-88)

2. That the proposed construction conforms with all other applicable ordinances and regulations of the Town of Derry.

APPENDIX XI-3

The following regulations shall apply to all lands designated as special flood hazard areas by the Federal Emergency Management Agency in its "Flood Insurance Study for the Town of DERRY, N.H." together with the associated Flood Insurance Rate Maps (FIRM) and Flood Boundary and Floodway maps of the Town of DERRY, N.H., dated April 15, 1981, which are declared to be a part of this ordinance.

Item I - Definition of Terms

"AREA OF SHALLOW FLOODING" means a designated AO, AH, or VO zone on a community's Flood Insurance Rate Map (FIRM) with a one percent or greater annual chance of flooding to an average depth of one to three feet where a clearly defined channel does not exist, where the path of flooding is unpredictable and where velocity flow may be evident. Such flooding is characterized by ponding or sheet flow.

"AREA OF SPECIAL FLOOD HAZARD" is the land in the flood plain within a community subject to a one percent or greater chance of flooding in any given year. The area may be designated as Zone A on the FHBM. After detailed ratemaking has been completed in preparation for publication of the FIRM, Zone A usually is refined into Zones A, AO, AH, A1-30, AE, A99, Vo or V1-30, VE or V.

"BASE FLOOD" means the flood having a one percent chance of being equaled or exceeded in any given year.

"BASEMENT" means any area of the building having its floor subgrade (below ground level) on all sides.

"BUILDING" -- see "structure".

"BREAKAWAY WALL" means a wall that is not part of the structural support of the building and is intended through its design and construction to collapse under specific lateral loading forces without causing damage to the elevated portion of the building or supporting foundation.

"COASTAL HIGH HAZARD AREA" means the area subject to high velocity waters, including but not limited to hurricane wave wash or tsunamis. The area is designated on a FIRM as Zone V1-30, VE or V.

"DEVELOPMENT" means any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations.

"FLOOD OR FLOODING" means: A general and temporary condition of partial or complete inundate of normally dry land areas from:

1. The over flow of inland or tidal waters.
2. The unusual and rapid accumulation of runoff of surface waters from any source.

"**FLOOD BOUNDARY AND FLOODWAY MAP**" (FLOODWAY) is an official map of the community, on which the Federal Emergency Management Agency (FEMA) has delineated the "Regulatory Floodway". This map should not be used to determine the correct flood hazard zone of base flood elevation, the Flood Insurance Rate Map (FIRM) will be used to make determinations of flood hazard zones and base flood elevations.

"**FLOOD ELEVATION STUDY**" means an examination evaluation and determination of flood hazards and, if appropriate, corresponding water surface elevations, or an examination, evaluation and determination of mudslide (i.e. mudflow) and/or flood-related erosion hazards.

"**FLOOD HAZARD BOUNDARY MAP**" (FHBM) means an official map of a community, issued by the Federal Emergency Management Agency, where the boundaries of the flood, mudslide (i.e. mudflow) related erosion areas having special hazards have been designated as Zones A, M, and/or E.

"**FLOOD INSURANCE RATE MAP**" (FIRM) means an official map of a community, on which the Federal Emergency Management Agency has delineated both the special hazard areas and the risk premium zones applicable to the community.

"**FLOOD INSURANCE STUDY**" see "flood elevation study".

"**FLOOD PLAIN**" or "flood-prone area" means any land area susceptible to being inundated by water from any source (see definition of "flooding").

"**FLOOD PROOFING**" means any combination of structural and non-structural additions, changes or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures and their contents.

"**FLOODWAY**" -- see "regulatory flooding".

"**FUNCTIONAL DEPENDENT USE**" means a use which cannot perform its intended purpose unless it is located or carried out in close proximity to water. The term includes only docking facilities, port facilities that are necessary for the loading and unloading of cargo or passengers and ship building and ship repair facilities, but does not include long-term storage or related manufacturing facilities.

"**HIGH ADJACENT GRADE**" means the highest natural elevation of the ground surface prior to construction next to the proposed walls of a structure.

"**LOWEST FLOOR**" means the lowest floor of the lowest enclosed area, (including basement). An unfinished or flood resistance enclosure, usable solely for parking of vehicles, building access or storage in an area other than a basement area is not considered a building's lowest floor, provided, that such enclosure is not built so as to render the requirements of this ordinance.

"MEAN SEA LEVEL" means, for the purposes of the National Flood Insurance Program, the National Geodetic Vertical Datum (NGVD) of 1929 or other datum, to which base flood elevations shown on a community's Flood Insurance Rate Map are referenced.

"MANUFACTURED HOME" means a structure, transportable in one or more sections, which is built on a permanent chassis and is designed for use with or without a permanent foundation when connected to the required utilities. For flood plain management purposed the term "manufactured home" includes park trailers, travel trailers and other similar vehicles placed on a site for greater than 180 consecutive days. For insurance purposes the term "manufactured home" does not include park trailers, travel trailers and other similar vehicles.

"MANUFACTURED HOME PARK OR SUBDIVISION" means a parcel (or contiguous parcels) of land divided into two or more manufactured home lots for rent or sale.

"100-YEAR FLOOD" -- see "base flood".

"REGULATORY FLOODWAY" means the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot at any point. These areas are designated as floodways on the Flood Boundary and Floodway Maps.

"RIVERINE means relating to, formed by, or resembling a river (including tributaries), stream, brook, etc.

"SPECIAL FLOOD HAZARD AREA" means an area having special flood, mudslide (i.e. mudflow) and/or flood-related erosion hazards and shown on an FHBM or FIRM as Zone A, AO, A1-30, AE, A99, AH, VO, V1-30, VE, V, M, or E. (See Area of Special Flood Hazard)

"STRUCTURE" means for flood plain management purposes, a walled and roofed building, including a gas or liquid storage tank, that is principally above ground, as well as a manufactured home.

"START OF CONSTRUCTION" includes substantial improvement, and means the date the building permit was issued, provided the actual start of construction, repair, reconstruction, placement or other improvement was within 180 days of the permit date. The actual start means either the first placement of permanent construction of a structure on a site, such as the pouring of slab or footings, the installation of piles, the construction of columns, or any work beyond the state of excavation; or the placement of a manufactured home on a foundation.

Permanent construction does not include land preparation, such as clearing, grading and filling; nor does it include the installation of streets and/or walkways; nor does it include excavation for a basement, footings, piers, or foundations or the erection of temporary forms; nor does it include the installation on the property of accessory buildings, such as garages or sheds not occupied as dwelling units or not part of the main structure.

"**SUBSTANTIAL IMPROVEMENT**" means any combination of repairs, reconstruction, alteration or improvements to a structure in which the cumulative cost equals or exceeds fifty (50%) percent of the market value of the structure. The market value of the structure should be:

1. The appraised value of the structure prior to the start of the initial repair or improvement, or
2. In the case of damage, the value of the structure prior to the damage occurring.

For the purpose of this definition "substantial improvement" is considered to occur when the first alteration of any wall, ceiling, floor or other structural part of the building commences, whether or not that alteration affects the external dimensions of the structure. The term does not, however, include any project for improvement of a structure required to comply with existing health, sanitary or safety code specifications which are solely necessary to assure safe living conditions or any alteration of a structure listed on the National Register of Historic Places.

"**V-ZONE**" -- see "coastal high hazard area".

"**WATER SURFACE ELEVATION**" means the height, in relation to the National Geodetic Vertical Datum (NGVD) of 1929, (or other datum, where specified) of floods of various magnitudes and frequencies in the flood plains or coastal or riverine areas.

APPENDIX XI-4

Section 11 - EARTH REMOVAL ORDINANCE

AUTHORITY - By the authority granted in RSA 155-E and in tl interest of public health, safety and general welfare for th Town of Derry this ordinance is hereby established and effectiv December 10, 1987

GENERAL

1.01 In accordance with the procedures, standards and conditions hereinafter specified, the Planning Board may permit the excavation or grading, filling or removal from any lot of any earth, loam, topsoil, sand, gravel, clay or stone. The purpose of this section is to protect the ecological processes which are depended on physiography; to protect well water supplies; minimize rapid surface runoff of rain water and melt water; preserve a cover crop on the land to prevent erosion and control any excavation that may create a safety hazard or health hazard to the public or to adjacent property owners, or be detrimental to the immediate neighborhood or to the Town.

1.02 The provisions of this ordinance shall be inapplicable to:

A. The construction of a wall, driveway, road, sewer or water line, fence, sidewalk or the landscape gardening of the property upon which excavation is taking place.

B. The removal by a person of topsoil from one part of his land to another part of the same premises, when such removal is necessary as an accessory use or is made for the purpose of farming, landscaping or improving said property.

C. Grading and filling where no topsoil, earth, sand, gravel, rock or other substance is removed from the premises.

D. An excavation which is made solely for the purpose of the construction of a structure upon and where the property is excavated.

PERMITS

2.01 Before any excavation (except one to which this ordinance is inapplicable, see Section 1.02) is commenced or any existing excavation is continued, the owner or lessee of the property shall obtain a written permit therefore from the Planning Board of the Town of Derry, New Hampshire.

2.02 The Planning Board shall issue said permit only when the applicant has submitted:

A. An application (together with a Fifty ($50) Dollar application fee in such form as the Planning Board shall prescribe) which shall contain at least:
   1. A written statement of the proposed work and the condition and final grades of the property after the work is completed and;
   2. The proposed dates of the commencement and estimated date of completion of work.

B. Maps and Plans
   1. Be drawn on a sheet of paper 14" x 24".